

# COMPUTER IMPLEMENTATION OF OPSET— A SELF CALIBRATING WATERSHED MODEL

A Thesis Submitted  
in partial Fulfilment of the Requirements  
for the Degree of  
MASTER OF TECHNOLOGY

By  
SHYAMAL KUMAR RAY

to the

DEPARTMENT OF CIVIL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY KANPUR  
DECEMBER, 1975

TO  
MY PARENTS

CE-1975-M-RAY-COM

CIR  
CENTRAL LIBRARY

Acc. No. A 45615

5 FEB 1976



20.12.75

21.

11

CERTIFICATE

THIS is to certify that the thesis entitled COMPUTER IMPLEMENTATION OF OPSET - A SELF CALIBRATING WATERSHED MODEL by Shyamal Kumar Ray is a record of work carried out under our supervision and that it has not been submitted elsewhere for a degree.

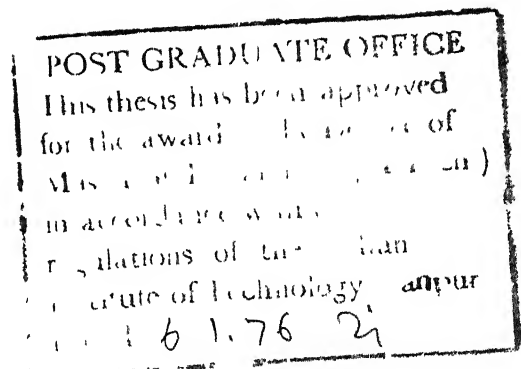
*(S. Ramaseshan)*

(S. Ramaseshan)  
Associate Professor  
Department of Civil Engg.  
Indian Institute of Technology  
Kanpur

*(V. Laxminarayana)*

(V. Laxminarayana)  
Assistant Professor  
Department of Civil Engg.  
Indian Institute of Technology  
Kanpur

December, 1975





## ACKNOWLEDGEMENTS

I take this opportunity to express my deep sense of gratitude and profound regard to Dr. S. Ramaseshan and to Dr. V. Laxminarayana for their invaluable guidance and constant encouragement which were vital to the success of this effort.

Thanks are due to the Director, Indian Meteorological Department, Delhi, the Director, Agricultural Meteorology, Poona and the other concerned departments of the Government of India for supplying the necessary data to complete this work.

I want to express my thanks to the authorities and the staff of the Computer Centres at IIT Kanpur and at IIT Madras for their help at different stages of my computer work.

I am also thankful to my friends Messrs R. Katarya, N. Banerjee, P.P. Chattopadhyay, S.P. Rajagopalan, V.K. Sehgal, A. Debchoudhuri, Anil Nigam, Ravi Shankar, K.C. Dwivedi, K.K. Kedia, K.N. Paul, A.P. Majumdar and Miss K. Majumdar for their help from time to time.

Thanks are also due to Mr. J.C. Verma for drawing work and to Mr. J.K. Misra for neat and elegant typing.

SHYAMAL KUMAR RAY

## CONTENTS

<u>Chapter</u>		<u>Page</u>
	CERTIFICATE	ii
	ACKNOWLEDGEMENTS	iii
	CONTENTS	iv
	LIST OF TABLES	vii
	LIST OF FIGURES	viii
	DICTIONARY OF VARIABLES	ix
	SYNOPSIS	x
1.	INTRODUCTION	1
	1.1 Hydrologic Cycle and Processes	1
	1.2 Mathematical Modeling and Analysis	4
	1.3 Simulation	7
	1.3.1 Streamflow Simulation Models	8
	1.3.2 Conceptual Models	10
	1.4 Statement of the Problem	16
	1.5 Scope of the Study	16
2.	DETAILS OF OPSET PROGRAM	17
	2.1 Kentucky Watershed Model	17
	2.1.1 General Description	17
	2.1.2 Flow Chart of KWM	18
	2.1.3 Input Data to KWM	20
	2.2 OPSET	20
	2.2.1 Definition of OPSET and Purpose of KWM	20
	2.2.2 Parameters Estimated by OPSET	21
	2.2.3 Physical Significance of Parameters	22
	2.2.4 Parameter Estimation Criteria	24

<u>Chapter</u>	<u>Page</u>
2.3 Parameter Estimation	24
2.3.1 Recession Constants	24
2.3.2 Runoff Volume Parameters	25
2.3.3 Surface Volume Parameters	32
2.3.4 Channel Routing Parameters	32
2.4 Parameters Directly Estimated From Watershed Characteristics	33
2.5 Earlier Studies Using OPSET	35
3. IMPLEMENTATION OF OPSET PROGRAM	37
3.1 Important Characteristics of the Program	37
3.1.1 Program Size and Memory	37
3.1.2 Computer Time	38
3.1.3 TRIPS	38
3.1.4 Language	39
3.2 Modifications	39
3.3 Additions and Alterations	40
3.4 Time Spent on Collecting the Data and Implementing OPSET	43
3.5 Factors Affecting the Efficiency of the Program	43
4. MODELING OF THE INDIAN BASIN AND THE RESULTS	44
4.1 Description of the Basin	44
4.2 Data Availability	44
4.2.1 Measurable Watershed Data	44
4.2.2 Meteorological Data	49
4.3 Simulation Analysis	51
4.3.1 Initialization of Parameter Values	51
4.3.2 Control Options	52
4.4 Output Parameters Using the Test Data	53

<u>Chapter</u>	<u>Page</u>
5. DISCUSSIONS AND CONCLUSIONS	64
5.1 Discussion of the Results	64
5.1.1 SSQM	64
5.1.2 Test Data	64
5.1.3 Indian Data	64
5.2 Conclusions and Scope of Further Studies	69
REFERENCES	71
APPENDIX COMPUTER PROGRAM	73

## LIST OF TABLES

<u>Tables</u>	<u>Page</u>
1. Interception Values for Various Types of Cover	33
2. Manning's Roughness Coefficient for Overland Flow for Various Surface Types	48
3. Initial Values of Parameters	51
4. Comparison of Obtained Parameter Values with those given in the Ref. 8.	53
5. Comparison of Recorded and Synthesized Monthly Flows for the Test Data	54
6. Comparison of Recorded and Synthesized Hydrograph Peaks for the Test Data	54
7. Recorded and Synthesized Stream Flow For the Year 1971-72	55
8. Comparison of Recorded and Synthesized Hydrograph Peaks for the Year 1971-72	55
9. Recorded and Synthesized Streamflow for the Year 1969-70	56
10. Recorded and Synthesized Hydrograph Peaks for the Year 1969-70	56
11. Optimum Parameter Values Obtained for an Indian Basin	57
12. Recorded Flows for Test Data at Wood Creek, London, Ky., USA, 1955-56	58
13. Synthesized Flow for Test Data at Wood Creek, London, Ky., USA, 1955-56.	59
14. Recorded Daily Flows (Indian Basin, 1971-72)	60
15. Synthesized Daily Flows (Indian Basin, 1971-72)	61
16. Recorded Daily Flows (Indian Basin, 1969-70)	62
17. Synthesized Daily Flows (Indian Basin, 1969-70)	63

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.	Schematic of Hydrologic Cycle.	5
2.	Schematic Flow Chart of KWM	19
3.	Schematic Diagram of Parameter Optimization Procedure	22
4.	Model for Estimating the Upper Zone .Storage Component of Surface Detention	29
5.	Model for Estimating Infiltration Entering Ground Water Storage	29
6.	Model for Estimating Actual Expotranspiration.	30
7.	Model for Estimating Infiltration Capacity.	31
8.	Plan of the Basin	45
9.	Test Data Wood Creek, USA, Water Year 1956 (Recorded and Synthesized Monthly Flows)	65
10.	Indian Basin Water Year 1971-72 (Recorded and Synthesized Daily Flows),	67
11.	Indian Basin Water Year 1969-70 (Recorded and Synthesized Daily Flows)	68 A

# DICTIONARY OF VARIABLES

ABX90	Antecedent Evaporation Index, Decay Rate = 0.90
AREA	Area of Watershed
BFRC	Base Flow Recession Constant
BIVF	Basic Interflow Volume Factor
BMIR	Basic Maximum Infiltration Rate Within Watershed
BUZC	Basic Upper Lone Storage Capacity Factor
CHCAP	Channel Capacity - Indexed to Basic Outlet
CN	1 = A.M., 2 = P.M.
CONOPT	Control Option
CSRX	Channel Storage Routing Index
DATE	Current Day of the Month
DAY	Current Day of the Year
DIV	Diversion Into Basin, Mean Daily Flow
DEET	Dated Potential Evapotranspiration
DPY	Days per Year
DRH1	Dated Recorded Hourly Precipitation
DRSF	Dated Recorded Streamflow
DRSGP	Dated Recorded Storage Gauge Precipitation
ETLF	Evapotranspiration Loss Factor
FIMP	Fraction of the Watershed Being Impervious
FSRX	Flood Plain Storage Routing Index
FWTR	Fraction of the Watershed Being Water
GWETF	Ground Water Evapotranspiration Factor
HOUR	Current Hour of the Day
HRF	First Hour of Loop
HRL	Last Hour of Loop
IFRC	Interflow Recession Constant
ISGRD	Current Storage Gauge Rainfall Day
IWBG	Index Number of Weather Bureau Precipitation Gauge

KRD	Counter for Reading Data Arrays
KWM	Kentucky Watershed Model
LZC	Lower Zone Storage Capacity
LZS	Current Lower Zone Storage
MEDCY	Month End Dates - Calendar Year
MNRC	Minimum Number of Rough Cycles
MONTH	Current Month of the Year
NCTRI	Number of Current Time Routing Increments
NPTR	Number of First Trip to Be Run For a Given Station Year
NLTR	Number of Last Trip To Be Run For a Given Station Year
NSGRD	Number of Storage Gauge Rainfall Days
OTMN	Overland Flow Manning's N
OTMNI	Overland Flow Manning's N, Impervious Surfaces
OTSL	Overland Flow Surface Length
OTSS	Overland Flow Surface Slope
SIAC	Seasonal Infiltration Adjustment Constant
SIK	Current Storage Routing Index
JSQM	Sum of the Squares of the Monthly Flow Deviations
UBWF	Subsurface Water Flow Out of the Basin
UZC	Seasonal Upper Zone Storage Capacity Factor
SWM	Stanford Watershed Model
'RIP	Counter Specifying Program Portions
IZC	Upper Zone Storage Capacity
INTMR	Vegetative Interception - Maximum Rate
EAR	Last Two Digits of Current Year



## SYNOPSIS

Shyamal Kumar Ray  
Department of Civil Engineering  
Indian Institute of Technology, Kanpur  
COMPUTER IMPLEMENTATION OF OPSET - A SELF CALIBRATING  
WATERSHED MODEL

The present study is basically related to the implementation of OPSET, a self calibrating watershed model program, to the computer system IBM 7044 and IBM 370/155 and the application of this to an Indian watershed to find out the optimum set of some parameter values which influence the runoff in a watershed greatly. Test data are available to implement the program. For the Indian watershed the measurable watershed parameters and other climatological data are collected from different places.

Physical description of the watershed under study is given and the definitions and magnitudes of the measurable watershed parameter values are also presented here. While optimizing the parameter values the main objective was to synthesize the streamflow and hydrograph peaks as closely as possible with those of recorded values respectively. Synthesized and recorded values of flows are tabulated for comparison.

Changes are made inside the program where necessary and are given in this study. Ultimately the optimized parameter values obtained from OPSET program can be used in the Kentucky Watershed Model to use in ungauged watersheds.

## CHAPTER I

### INTRODUCTION

#### 1.1 Hydrologic Cycle and Processes:

Hydrology is a branch of physical geography. It deals with the origin and distribution of the waters of the earth.

The study of hydrology starts with the concept of hydrologic cycle. Water evaporated from the oceans and the free water surface of the land mass is transported by moving air masses. Under proper conditions the vapour is condensed to form clouds, which, in turn, may result in precipitation. The precipitation which falls upon land is dispersed in several ways. Part of the water is returned to the atmosphere by the processes of evaporation and transpiration. Of the remaining part, a portion passes over and through the surface soil to the stream channels and other portion penetrates deeper inside the earth to become part of the earth's ground water supply. Under the influence of gravity these surface waters and ground waters always move towards the lower elevation but a substantial quantity of these return to the atmosphere through the processes of evaporation and transpiration.

A review of the hydrologic cycle, particularly of those processes which are important in governing runoff rates, provides the best background for understanding the model in

this study namely OPSET, the basic logics of which are dependent on the Stanford Watershed Model. The processes are described briefly in the following paragraphs.

Moisture held on vegetative surfaces is known as Interception Storage. This is dependent on type and density of vegetative cover. This reduces the runoff but its effect is less in large storms compared to small storms.

Precipitation not held by vegetative cover but held in hollows and behind ridges on soil surface is known as Depression Storage. This is also more effective in reducing runoff during small storms than during larger storms. Depression storage capacity is generally larger than interception storage capacity and is governed primarily by the roughness of the soil surface, human activity and watershed topography. Steep slopes reduce the depression storage capacity. In arid climate the less frequent runoff does not wash out the ridges and depression storage is greater.

A portion of the water in contact with the soil surface infiltrates into the soil which may return to the stream channel as Interflow or Baseflow or may be used by vegetation as evapotranspiration. Infiltration into the ground depends generally on the soil permeability, surface characteristics, presence or absence of vegetation, etc. But freezing of the upper zone, rising of the underground water table and low permeability at moderate depths are some factors for reduced infiltration rate.

High evapotranspiration rates will deplete the soil moisture between storms and consequently increase the infiltration rate. Evaporation from soil surfaces and exposed water surfaces depends on the degree of exposure, air temperature, water temperature, wind velocity, atmospheric pressure and percent solids in the water. Moisture loss through transpiration depends upon the degree of vegetative cover and other climatological factors. Urban development greatly increases the relative imperviousness of a watershed.

Water which doesnot percolate to the water table (to later appear as baseflow) may proceed toward the stream in two ways:(1) it may travel over the land surface ( overland flow); or 2) it may travel partially through and partially above ground (interflow). The time lag of overland flow is governed by the slope, distance to the nearest collector stream and roughness of the soil surface. Overland flow is very rapid in impervious surfaces.

If the watertable is higher or if there is an impervious layer at a shallow depth, the interflow increases. Rapid flow through the soil layers is seen in most permeable soils. Quantity of interflow is dependent on the local infiltration capacity.

Overland flow, interflow, baseflow enter the channel system at different, scattered points in a watershed. The

channel inflows combine as they flow downstream and ultimately reach the gauging station in the stream. This channel flow rate depends on the slope, size, shape, and hydraulic roughness.

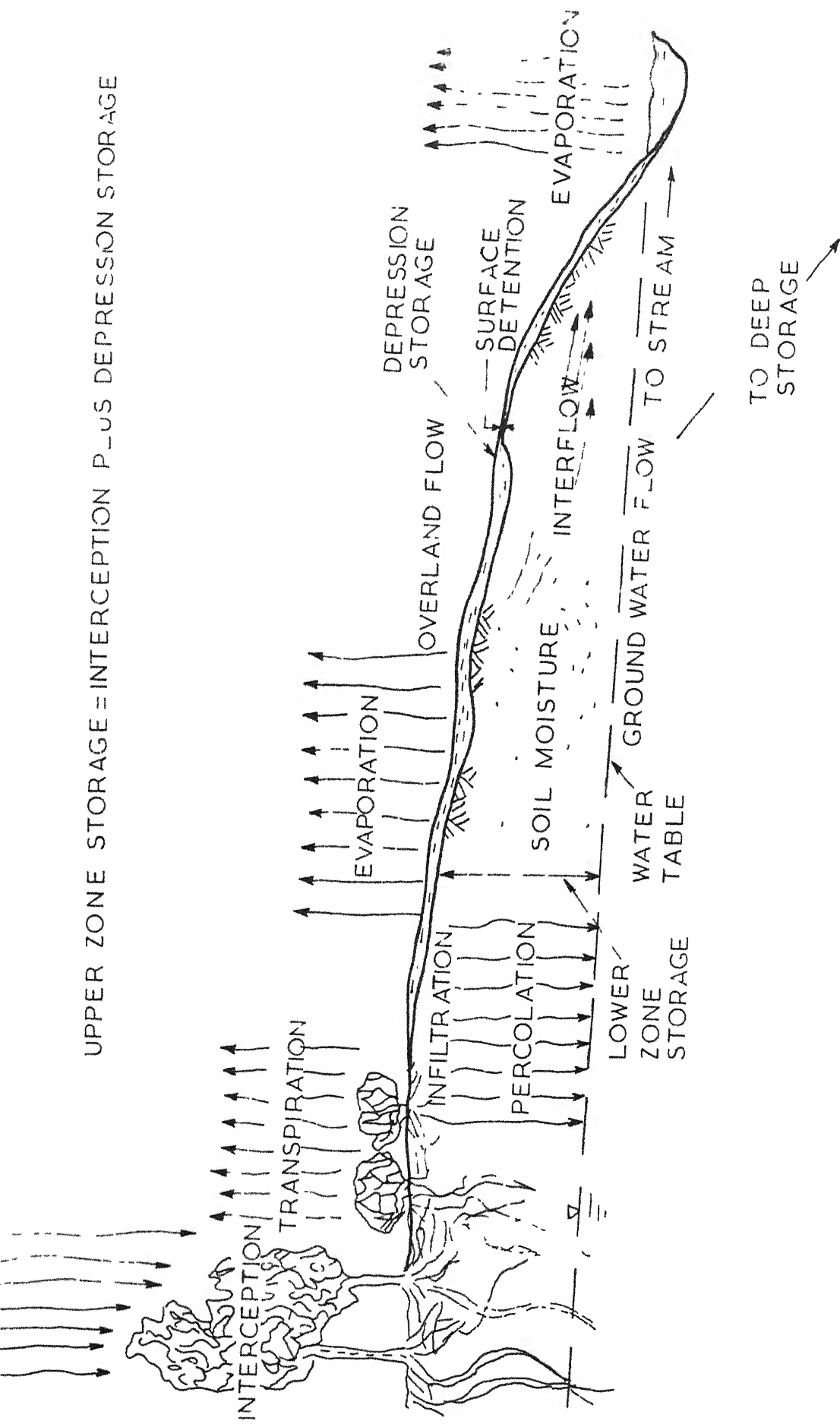
A schematic diagram of the hydrologic cycle is shown in Fig. 1.

## 1.2 Mathematical Modeling and Analysis:

Full synthesis of the hydrologic cycle is practically impossible due to vast complexity of the systems involved in the study, inadequacy of the knowledge now available and the knowledge likely to exist in the foreseeable future. The other way is to solve the practical technological problems by establishing workable relationships between measurable parameters in the hydrologic cycle.

'Systems investigation' is needed in hydrology to establish quantitative relationships between precipitation and runoff, which can be used for 'reconstruction or prediction (ROP) of flood sequences and watershed yields. System investigation methods are (a) parametric and (b) stochastic. In the present work parametric study is done.

Parametric hydrology is the development of relationships among physical parameters involved in hydrologic events and the use of these relationships to generate, or synthesize, non-recorded hydrologic sequences [1]. Among all the studies



UPPER ZONE STORAGE = INTERCEPTION PLUS DEPRESSION STORAGE

FIG.1 SCHEMATIC OF HYDROLOGIC CYCLE

made in parametric hydrology only the general non-linear analysis is independent of detailed knowledge of physical hydrology where emphasis is centred on topics of study. In the method of correlation analysis various combinations of variables are tested to explore the significance of their effects in the hydrologic system. The combination, among those investigated, that yields a relationship most closely approximating the recorded output function in terms of the recorded input function and other arbitrary parameters is adopted as the best prediction equation.

In system analysis, the synthetic models in hydrology are dependent on the continuity equation of the form,  $I = Q + \Delta S$ , where  $I$  = total inflow,  $Q$  = total outflow and  $\Delta S$  = change in internal storages for any given time interval. Any system like this, defined by the continuity of matter, is known as 'closed' system.

Through the general non-linear analysis, which started a few years ago, one can find out the relationships between partial inputs and partial outputs to be established independently, subject to some conditions of mathematical continuity and boundedness. It is not necessary to satisfy physical continuity conditions among the total input, total output and inner storage. When input and/or output represents only partial form of the total input or total output of the system, the system is called 'open'. Considering a hydrologic unit as an

open system one has obvious advantage in that it bypasses the need to evaluate component inputs and outputs.

Hydrologic system cannot be treated as analytic system because current mathematical knowledge is insufficient to evaluate the nonlinear kernels of the functions of series when multiple inversion is not possible due to complex input.

Physical simulation, for a hydrologic system, is not possible due to limited data. Ultimately digital simulation helps in this regard.

### 1.3 Simulation.

To simulate means to duplicate the essence of the system or activity without actually attaining reality itself. It is used to circumvent the difficulties of duplication of environment, of mathematical formulation, of lack of analytical solution techniques, or of experimental impossibilities.[2].

In hydrology simulation is used to correlate the observed hydrological behaviours to the factors which influence these and to predict the behaviour of watersheds where observed data are unavailable or incomplete. For this, large quantities of physical data on rainfall, evapotranspiration, streamflow, and other related variables are collected. Qualitative knowledge about the hydrological cycle is reasonably complete and interaction between major components such as rainfall intensity and infiltration rates can be logically explained. Still the



extension of qualitative knowledge to quantitative procedures is challenging. The land phase of the hydrological cycle contains complex interactions that are difficult to document from observed data, and the volume of data that must be analysed is formidable. Streamflow simulation attempts to develop algorithms of hydrological processes for quantitative calculations. In the present study hydrological reactions are assumed deterministic.

Since we are dealing with a physical system, a digitally simulated model deals with partial differential equations for rainfall, evapotranspiration, streamflow etc. This is too complex. Further, detailed and accurate data for soil moisture, overland flow etc. are not available in our country. Therefore, hydrologic basin models with lumped elements have been used with different levels of details.

### 1.3.1 Streamflow simulation models:

There are many models for streamflow simulation, few of which are described here. Three types of models are generally used these days. These are (a) Mathematical Models, (b) Retention Models and (c) Conceptual Models.

In the study of hydrology with mathematical modeling, run-off process can be analysed. Hydrometeorological characteristics which define the behaviour of catchments and the construction of mathematical models which approximately

reflect the process of the runoff are complementary. In modeling runoff some difficulties are encountered such as lack of basic data combined with considerable noise level and uncertainty of some links in the hydrologic process namely the characteristics of water movement in the drainage basin, its depth and the circumstances of its emergence on to the surface, followed by routing through the channel. To overcome all these, some hypotheses in models are used to match model with the natural data. The simplest of this kind is a model of snow-melt runoff on the surface of a mountain.

In Retention Model, a catchment is regarded as an interconnected system of catchment units and channel units. Each catchment unit consists of a retention storage and a runoff storage. The retention storage does not meet the stream flow and is composed of capillary soil moisture, precipitation intercepted by vegetation, and some parts of the depression, ground water and channel storages. The runoff storage consists of the water that is likely to become streamflow, including over land flow, 'free' water moving through soil or litter, ground water and storage in minor channels. Informations of leakage, channel transmission losses are taken into account, if available. This model was originally suggested for analysing the effects of vegetation and soils on runoff volumes but it seems just as suitable for short term forecasting of floods due to rainfall [3].

The objective of a Conceptual Catchment Model is to simulate as accurately as possible the streamflow hydrograph under natural conditions and also to evaluate the modifications to natural flows resulting from man-made physical changes or management practices. Ideally, a conceptual catchment model should satisfy the following four conditions for maximum usefulness in river forecasting:

- (1) It should represent the significant hydrological processes in a rational manner;
- (2) It should contain the minimum number of parameters required for adequate representation of the processes;
- (3) The values of the parameters should be measurable or be significantly correlated to easily measurable characteristics and
- (4) The model should contain procedures for updating as new information becomes available, in a rational if not optimal manner.

There is still much to be learnt about the various phases of the hydrologic cycle and research is being carried out to increase the knowledge of them.

### 1.3.2 Conceptual models:

The basic philosophy of some of the well known conceptual models are presented below.

# 1. Stanford Watershed Model (SWM):

This is the best known of the current conceptual models. A brief description only is given here and the fuller description is given in Chapter 2. The SWM simulates continuously the movement of water as it moves over, into and through the soil. It uses as input rainfall, snowmelt or both. Interception and storage losses must be satisfied initially. A portion of the runoff comes over the impervious surface and joins the streamflow and the rest passes over the pervious surface and is subject to the soil moisture conditions. Infiltration capacities vary from watershed to watershed. Detention storage, overland flow and interflow are due to the accumulation of water on the upper zone. Water moves from upper zone to lower zone and ultimately joins the ground water storage. Water stored in the soil moisture zone is called lower zone storage. Lake evaporation from class A pan records is assumed to be potential evapotranspiration. Evapotranspiration is assumed to take place from interception storage, upper zone, lower zone and ground water storage but at different rates. Ground water runoff, interflow and surface runoff are routed separately and combined to produce outflow hydrograph. Hydrological processes are represented mathematically and the parameters involved in these mathematical quantities are obtained by the digital computer.

## 2. The Utah State Simulation Model:

This simulation model has been developed by the Utah State University. The computer needed for its solution is an analog computer. Its objectives are (i) the development of improved relations for describing the various hydrological processes and inter-connecting link between these processes, and (ii) the development of an analog computer having a high degree of flexibility and capability for the solution of hydrological and related problems.

The hydrologic balance of this model is given by,

$$P = I + \Delta M_s + SRO + \Delta G_s + GWO + ET \pm \Delta S_s$$

where,

$P$  = Precipitation,

$I$  = Interception loss,

$\Delta M_s$  = Change in soil moisture storage,

$SRO$  = Surface run-off,

$\Delta G_s$  = Change in ground water storage,

$GWO$  = Ground water run-off,

$ET$  = Evapotranspiration, and

$\Delta S_s$  = Change in surface storage.

Interception loss is a function of type and density of cover and precipitation.  $SRO$  is the excess of precipitation over the infiltration rate. Soil moisture storage is a function of infiltration, evapotranspiration, interflow and percolation

to ground water storage. The relation of actual to potential evapotranspiration rate is assumed to be a function of soil moisture deficiency. Percolation of ground water is dependent on soil moisture storage. Ground water runoff is a function of ground water storage. The increments of surface runoff, inter flow and ground water are routed separately through different amount of storage.

### 3. The Agricultural Research Service Model:

This model, responsible for agricultural research in the U.S., is based on infiltration theory approach. In this model first the depression storage on the surface must be satisfied. An assumption is made that some impeding stratum of the soil acts as a control on saturated flow. Therefore, the infiltration capacity ( $f$ ) of a surface soil approaches the low constant seepage rate ( $f_c$ ) of the impeding stratum as the overlying storage ( $S$ ) is exhausted by infiltration volumes ( $F$ ). The equation is as follows:

$$f = a (S - F)^{1.4} + f_c$$

where,  $a$  = percentage of area occupied by plant crowns, because plant roots connect large pores and provide continuous channel.

For this model, soil data are needed which permit determinations of soil porosities and occurrence of impeding strata.

Soils are grouped in accordance with their constant rate of infiltration after prolonged wetting. This constant rate is assumed as the seepage rate through the impeding strata. Porosities are classified as (i) pores (h), free water drainable by gravity, and (ii) pores, available water capacity (AWC), drainable by evapotranspiration. Recovery of available storage, by this means, is at the rate of seepage ( $f_c$ ) to the extent of freely drainable porosity. Further recovery of available storage capacity between the days of rain is at the rate of evapotranspiration (ET) to the extent of plant available water (AWC). Different values of  $a$ 's, plant root coefficients, are prepared relative to various land use and treatments. Potential ET is estimated from pan-evaporation with a seasonal consumptive use coefficient applied to obtain the actual evapotranspiration. Water in excess of infiltration and surface depression storage is assumed available for run-off and is routed by successive routing techniques to reproduce the out-flow hydrograph.

#### 4. The Columbia River Basin Model:

The input to this model is weighted rainfall plus computed snowmelt on a daily basis. This daily input is distributed into specific time period (3, 6 or 12 hours). The total runoff is calculated by multiplying rainfall, snowmelt or both by a percent coefficient which is a function of soil

moisture index. The soil moisture index at the end of a period is the soil moisture index at the beginning plus precipitation minus total run-off minus evapotranspiration for the same period. Evapotranspiration on rainy day is less and is obtained by multiplying the daily value by a coefficient. The percent of the total runoff contribution to base flow is computed as a function of a base flow infiltration index. The remaining runoff is separated into surface and subsurface components as a function of the total input rate. Components of surface, subsurface and baseflow runoff are routed separately, using a successive reservoir routing technique. It is also possible in this model to introduce rule curves for operation of reservoirs and/or to specify release schedules for all or selected reservoirs.

Studying all the above models it is observed that the Stanford Watershed Model is the best suited in this study, considering the availability of data. The Kentucky version of the Stanford Watershed Model known as Kentucky Watershed Model (KWM) was available with us for analysis.

KWM has a number of parameters. Estimation of these parameters is very time consuming. 'A self calibrating model' known as OPSUT is available for finding the best fit of values for the parameters so that simulated flow matches the recorded flow. This model uses hourly rainfall data, daily streamflow



data and yearly, daily or 10-daily average evaporation data besides several other types of data.

In India, there are nearly 400 self recording rain gauge stations. The data from these stations are yet to be used in detailed hydrologic modeling of basins. It seems possible to use KWM in order to model basins with hourly rainfall data. Hence, it is proposed to implement the OPSET program developed by the University of Kentucky and available with us and use it, if possible, to model a basin for which data are available.

#### 1.4 Statement of the Problem:

The objectives of the study are

- (1) to implement the OPSET programme for estimation of parameters of the KWM using the test data given in the original report [4], and
- (2) to estimate the parameters for a basin in India with the requisite data.

#### 1.5 Scope of the Study:

- (1) The implementation of OPSET on IBM 7044 and IBM 370/155 computer systems is done using the set of available test data.
- (2) Estimation of parameter values for a basin in India is done on the basis of available data.

Within the limitations of time, computer facilities, money and data availability, parameters are determined only for 2 years for the Indian basin.

## CHAPTER II

### DETAILS OF OPSET PROGRAM

#### 2.1 Kentucky Watershed Model:

##### 2.1.1 General Description:

The Kentucky Watershed Model (KWM) is the translated, revised and expanded version of the Stanford Watershed Model. Originally, the Stanford Watershed Model was written in a digital computer language SUBALGOL. James [5,6,7] translated it into FORTRAN IV and modified it. This version is known as KWM. As the basic logic of SWM and KWM are same, the description of Stanford Watershed Model is given here.

SWM is a systematic mathematical representation of the hydrologic processes in the hydrologic cycle. Mathematical formulations in the model are empirical for some of the processes.

In this model the major input data are evapotranspiration and rainfall. If snow is a significant part of precipitation, then snowfall data should also be given as input data. In addition, several other input parameters and control arrays must be selected based on Watershed behaviour, characteristics and data availability. The details of input parameters are given by James [5].

Output consists of synthetic streamflow, overland flow, interflow, baseflow, stream evapotranspiration (net and potential) and ground water storage. These hydrologic quantities can be obtained daily, monthly or annually as appropriate for use by the researcher.

### 2.1.2 Flow Chart of KWM:

A schematic flow chart of KWM is given in Fig. 2. In the above mentioned figure the boxes represent classifications of moisture storage. Arrows are the processes through which moisture moves from one type of storage to another type of storage. The vertical straight line from precipitation to subsurface flow with arrow downwards represents the flow of water through the porous media due to gravity. When moisture cannot move downward due to some restrictions, such as low permeability, moisture starts accumulating in the higher boxes. Water moves laterally and joins the stream when storage capacities of these boxes are exceeded. Ultimately, it goes out of the watershed. Vertical straight line with arrow upward indicates the withdrawal of water from all levels of storages due to radiation energy, and moisture needs of vegetation.

The path taken by incoming moisture is determined by the antecedent moisture storage, the magnitude of the assigned parameter values, the entry rate and the season of the year.

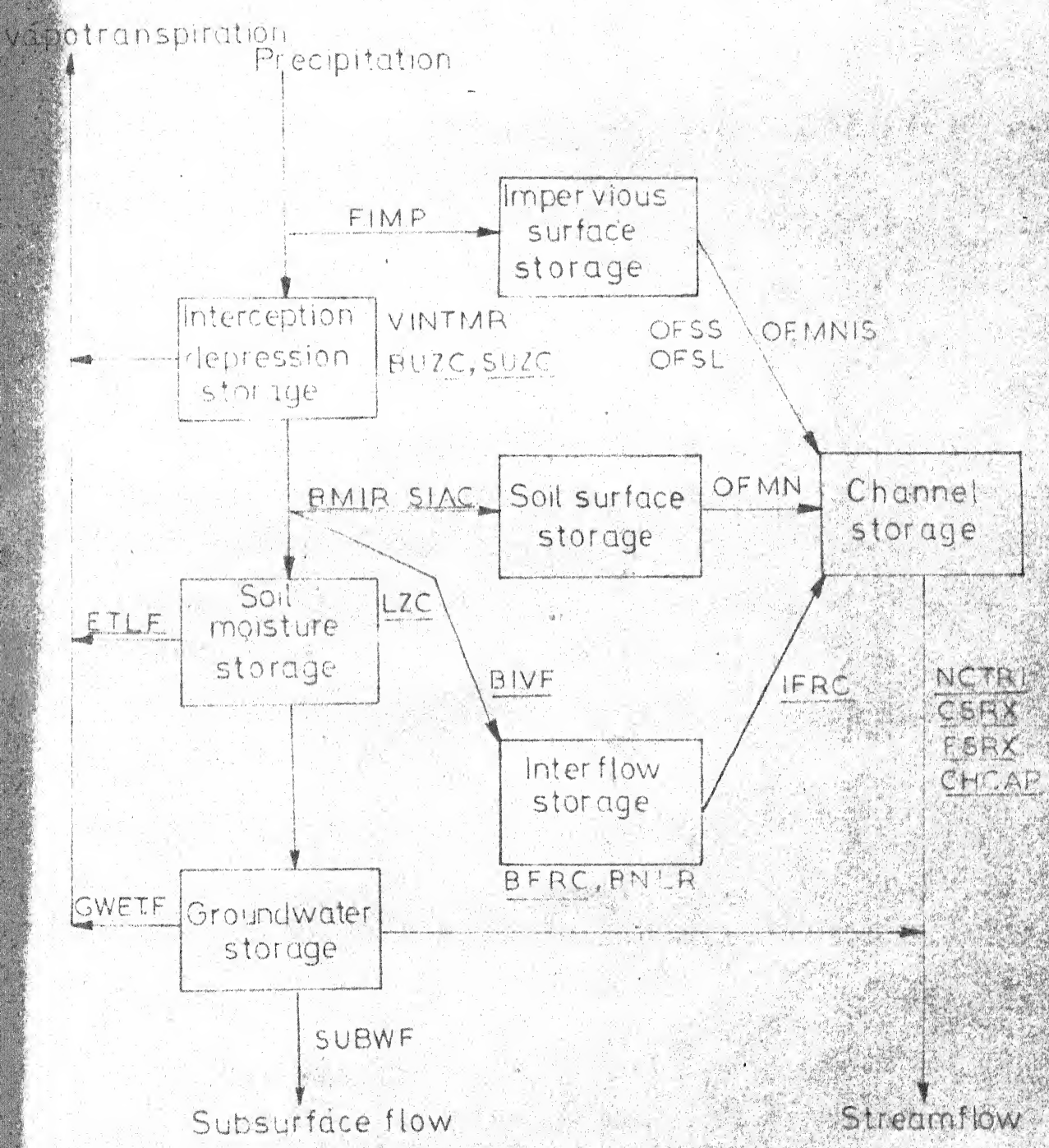


FIG.2 SCHEMATIC FLOW CHART OF KWM

The quantities appearing along the flow lines are the parameters which control the flow of moisture along those paths.

### 2.1.3 Input Data to KWM:

The input data required by SWM or Fortran KWM are divided into 6 groups as follows:

1. Data to specify the desired program options and required specific output.
2. Data to initialize the watershed soil moisture storage condition.
3. Data to establish climatological events.
4. Time-area histogram for watershed under study.
5. Data to assign values to the watershed parameters,
6. Recorded streamflow to compare with the synthesized flow.

## 2.2 OPSET:

### 2.2.1 Definition of OPSET and Purpose of KWM:

OPSET is a self calibrating model. It is called OPSET because of its objective to estimate the OPTimum SET of parameter values. Input parameters are those which can be directly measured by the user. Other parameters are repeatedly adjusted by OPSET to match the synthetic hydrograph with observed hydrograph until no further adjustment is possible. Optimum set of parameters are obtained from OPSET for different water year

for a watershed and then averaged. They can be used in KWM. KWM, in order to synthesize streamflows, uses these parameter values with much larger number of control options. A schematic diagram of parametric optimization procedure followed by OPSET program is shown in Fig. 3.

#### 2.2.2 Parameters Estimated by OPSET:

There are altogether 13 parameters to be determined by OPSET which are classified as follows. These parameters are underlined in Fig. 2.

##### Recession Constants:

1. IFRC - Interflow Recession Constant
2. BERC - Baseflow Recession Constant

##### Land Phase Parameters:

###### (a) Runoff Volume Parameters:

LZC - Lower Zone Storage Capacity,  
 BMIR - Basic Maximum Infiltration Rate Within Watershed,  
 SUZC - Seasonal Upper Zone Storage Capacity Factor,  
 ETLF - Evapotranspiration Loss Factor,  
 BUZC - Basic Upper Zone Storage Capacity Factor,  
 SIAC - Seasonal Infiltration Adjustment Factor.

###### (b) Surface Volume Parameters:

BIVF - Basic Interflow Volume Factor

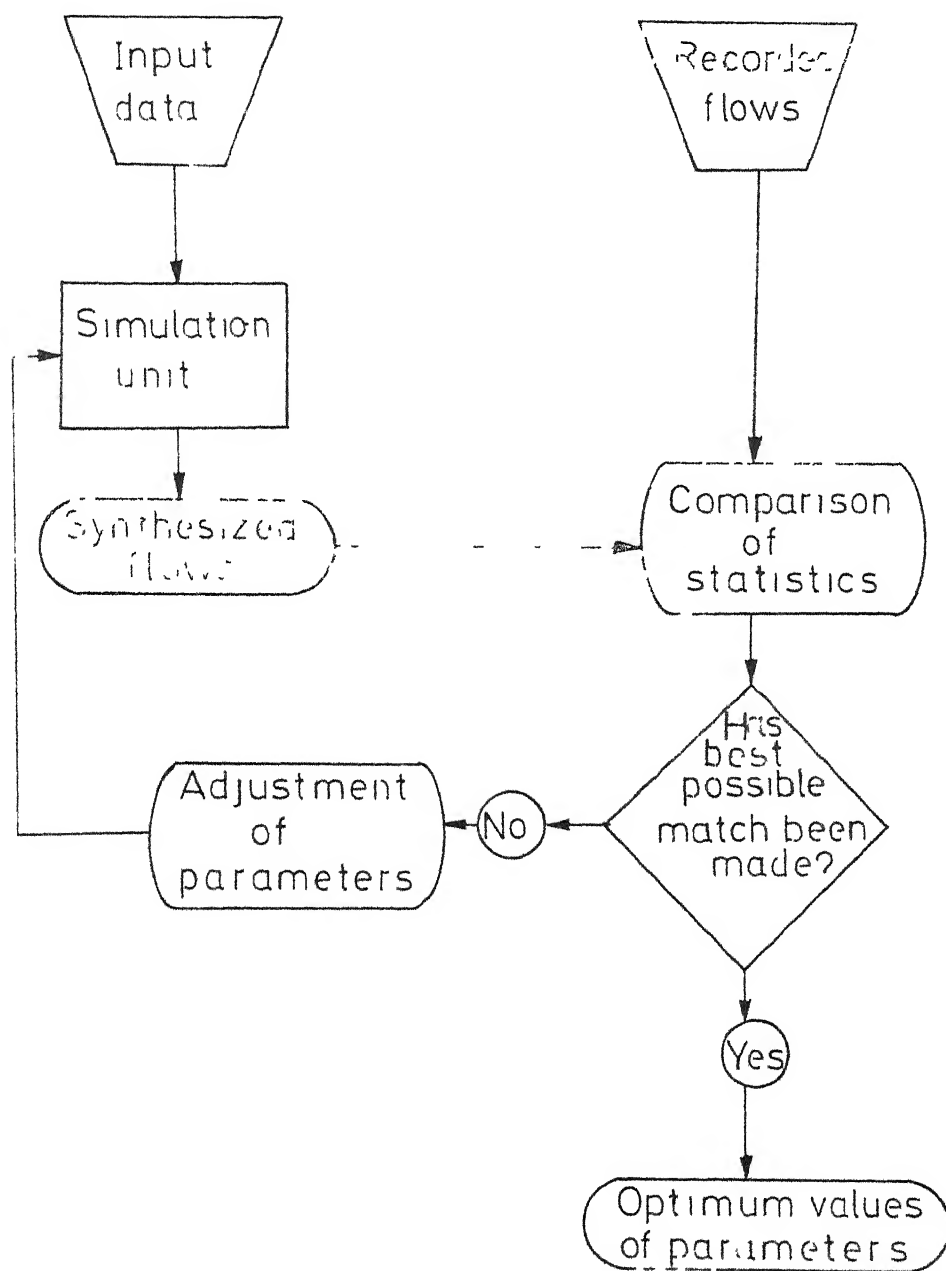


FIG. 3 SCHEMATIC DIAGRAM OF PARAMETER OPTIMIZATION PROCEDURE

### Channel Routing Parameters:

1. NCTRI - Number of Current Time Routing Increments,
2. CSRX - Channel Storage Routing Index,
3. FSRX - Flood Plain Storage Routing Index,
4. CHCAP - Channel Capacity - Indexed to Basin Outlet.

### 2.2.3 Physical Significance of Parameters:

Over a real watershed, the hydrologic processes are continually going on at rates varying with time and location. The movement of moisture at any point is in response to acting forces (gravity) counteracted by the resistance to moisture movement along a given flow path. The resultant moisture moves in low resistance zone. Physical factors governing the saturated and unsaturated flows include the size and shape of the particles, the porosity, orientation, and the moisture content of the area, viscosity and surface tension of water and information on how these factors vary over time and space. In this model lumped estimation process has been used. Option is there in SWM to divide the whole area into a number of segments. The estimate should also be lumped over a finite interval of time (15 mins. in SWM). They also can be lumped to a group of related hydrologic processes such as interception storage is added to depression storage in the SWM. Baseflow recession constants represent the cumulative effect of moisture movement along a large number of routes. Lumped



estimates imply that watershed parameters somehow aggregate the effects over space and time. Best values are those which give the synthesized flow close to the recorded flow. But this depends on the data measurement error, size of the area and length of time represented etc. One point is very important that the parameters which are best in 15 minutes time increments will not be the best in 60 minutes time increments [8].

#### 2.2.4 Parameter Estimation Criteria:

There are two criteria to choose the parameters which are to be estimated by the OPSET program. First, the parameters should be difficult to measure directly. Parameters like drainage area should not be estimated by matching synthetic flow with the recorded flow as it is easy to measure this to a satisfactory degree of accuracy. Second, the simulated flow sequences should be sensitive to the parameters. Considering the above two criteria the thirteen parameters mentioned before were chosen.

### 2.3 Parameter Estimation:

The procedure followed by OPSET program to estimate the parameters is outlined below.

#### 2.3.1 Recession Constants (BFR and IFRC):

Traditional graphical techniques to find out BFR (base flow recession constant) and IFRC (inter flow recession constant)

are time consuming. The recession sequence is selected by the subroutine RECESS. Maximum length of each sequence is 50 days and for each station year upto 20 flow sequences are selected. Minimum number of days needed to estimate a single recession constant is 2 and for 2 constants 4 days are needed. Longer sequences give better results. As recessions from very small flow do not give good results a criterion is used that the second day flow should be either greater than 10 cfs or greater than  $0.4 \times \text{AREA}$  (where AREA is the watershed area in sq. miles). Second day is the day after peak or the first day whose flow is actually used to find recession constants. The recession sequence is terminated by a flow rise exceeding  $0.1 \times \text{SQRT}(\text{AREA})$  cfs. After finding out the recession sequences through the subroutine RECESS the subroutine SET2RC and SET1RC are used to find the values of IFRC and BFRC.

Subroutine SET2RC is called first to estimate the two recession constants IFRC and BFRC. If the sequence starts with a relatively low flow and flat recession then it is assumed that only base flow is present and subroutine SET1RC is used. Here BFRC is found. If the value of BFRC does not come up between 0.6 and 1.2 the entire sequence is discarded.

### 2.3.2 Runoff Volume Parameters (LZC, BMIR, SUZC, ETLF, BUZC, SIAC):

In order of decreasing sensitivity these parameters are LZC, BMIR, SUZC, ETLF, BUZC and SIAC. The subroutine SETFVP

adjusts the values of five flow volume parameters LZC, SUZC, ETLF, BUZC and SIAC during the process of estimating the best set of values for the six flow volume parameters. In order to see how and to what degree each of these parameters affects runoff, a sensitivity study was made with the data for Elkhorn Creek, Frankfort, Kentucky, USA, for the year 1964. First of all a best set of parameter values were selected by trial and error. Then for each of six parameters 2 computer runs were made by varying that parameter keeping others constants. Each parameter had effect on simulated flow and differed with the changes of type of flow and changes in time of the year. BMIR is adjusted through the subroutine SETBMI and other five through SETFVP. These two subroutines function as unit and adjusts the six volume parameters simultaneously.

First of all, trial values are taken for these parameters and a year of streamflow is simulated. Then each parameter is adjusted by its adjustment rule. The new set of six values is used to simulate another year of streamflows, and this process continues until the simulated flows have smaller SSQM as computed by subroutine SETFDI. Recorded and simulated flows cannot match perfectly due to data and modeling difficulties.

Runoff volume parameters are defined as follows:

### 1. BUZC:

It is an index for estimating the capacity of the soil surface (upper zone) to store water in interception and depression storage. Wetter the underlying layer more will be the amount of water stored in this layer.

### 2. SUZC:

It is an index for estimating soil surface moisture storage capacity. Seasonal storage capacity changes due to summer vegetation and cultivation is taken care of by SUZC. BUZC and SUZC are used to compute the upper soil zone nominal storage capacity (UZC) by the following equation.

$$UZC = SUZC (AEX90) + BUZC (e^{-2.7} \times \frac{LZS}{LZC})$$

where,

AEX90 = Antecedent evaporation index ( $K = 0.90$ ),

$\frac{LZS}{LZC}$  = An index of the moisture content of the underlying soil,

e = Natural logarithm base.

### 3. LZC:

It is the soil-moisture storage capacity index which approximately equals the volume capacity of the soil to hold water. Decreasing LZC will be reducing the ability of soil to hold water and thus increasing the synthesized flow and the reverse when the value of LZC increases. Delayed infiltration

or percolation happens from the upper zone to the ground water and lower zone storages when UZS/UZC exceeds the value of LZS/LZC (Ref. Figs. 4 and 5).

#### 4. ETLF:

ETLF is an index used to estimate the maximum rate of evapotranspiration which could occur within the watershed under current conditions of soil moisture content. This maximum rate is then used to estimate current actual evapotranspiration in the manner depicted in Fig. 6. More trees in a watershed means higher value of ETLF and less simulated flows (Ref. Fig. 6).

#### 5. SIAC:

It is an evaporation-infiltration factor relating infiltration rates to evaporation rates to account for more rapid infiltration during warmer period. Higher the value of SIAC less is the runoff.

#### 6. BMIR:

It is the basic infiltration index used to control the rate of infiltration. Infiltration rates vary from point to point in a watershed and most runoff will be from points with smaller rates. A cumulative frequency distribution is used in SWM, varying linearly from zero to a maximum value (Ref. Fig. 7).

The equations relating maximum capacity to infiltration rates, applicable at any particular point in time (CMIR), are given by,

$$\begin{aligned} \text{CMIR} &= \frac{\text{Constant} \times \text{SIAM} \times \text{BMIR}}{\text{Function (LZS/LZC)}} \\ \text{SIAM} &= \text{Function (SIAC)} \\ \text{CIVM} &= \text{BIVF} \times \text{Function (LZS/LZC)} \end{aligned}$$

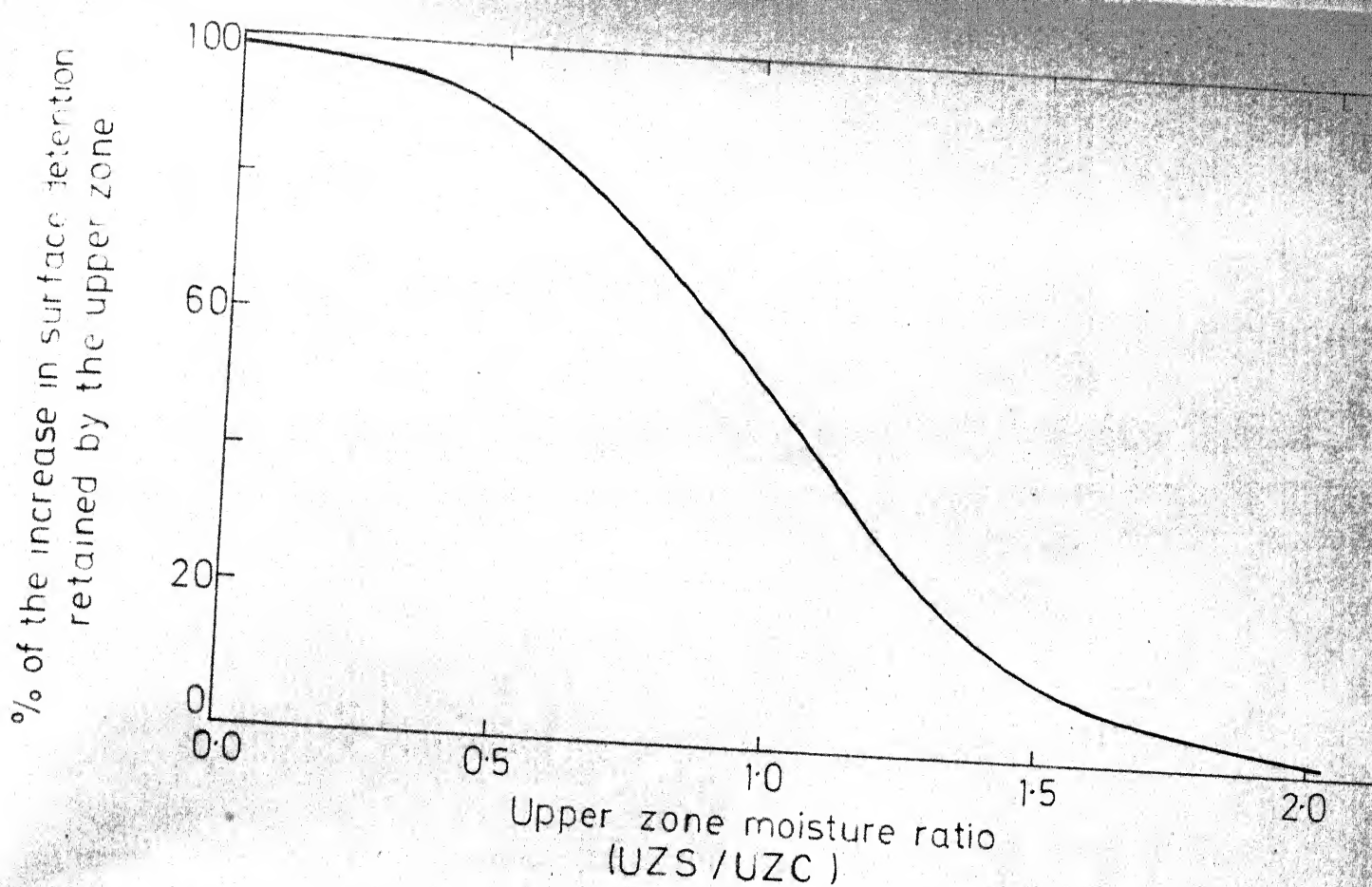


FIG.4 MODEL FOR ESTIMATING THE UPPER ZONE STORAGE COMPONENT OF SURFACE DETENTION

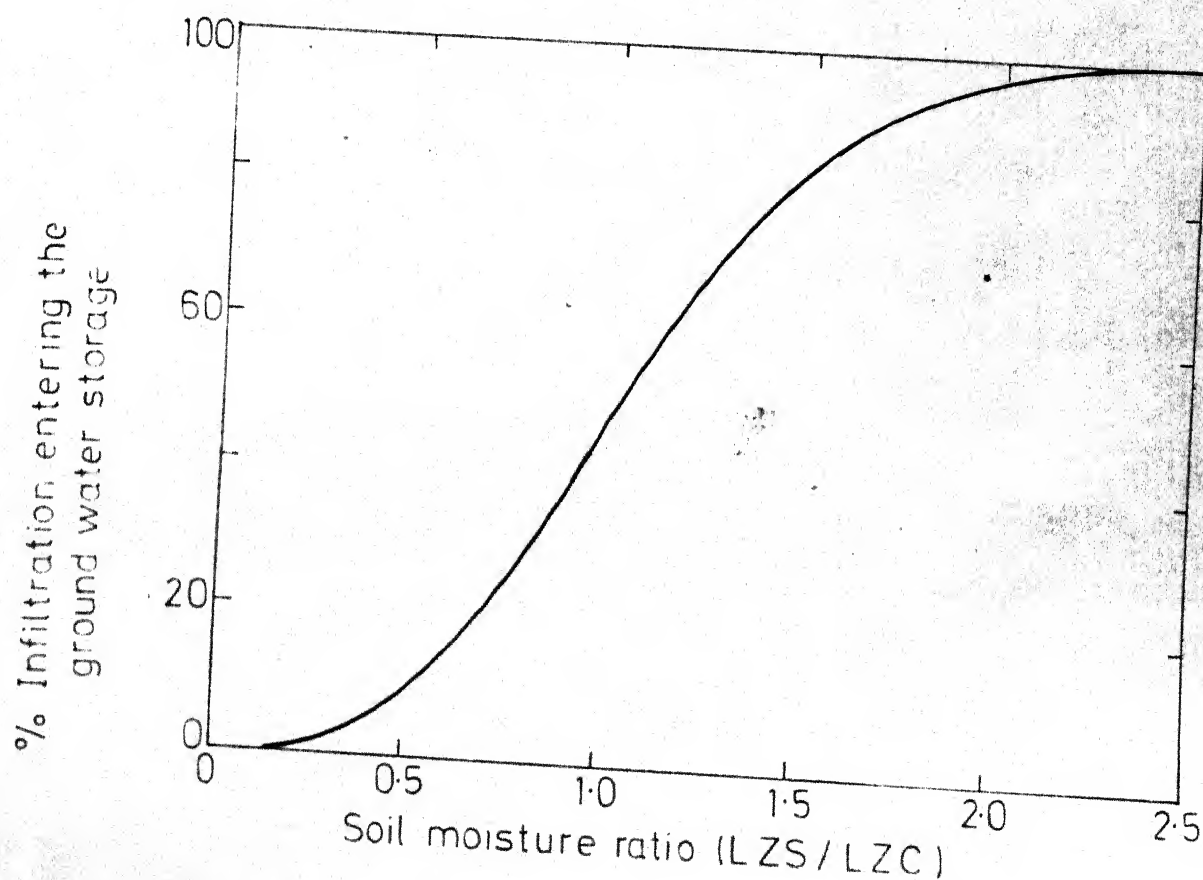


FIG.5 MODEL FOR ESTIMATING INFILTRATION ENTERING GROUNDWATER STORAGE

$$\text{Maximum rate} = \text{ETLF} * \text{LZS} / \text{LZC}$$

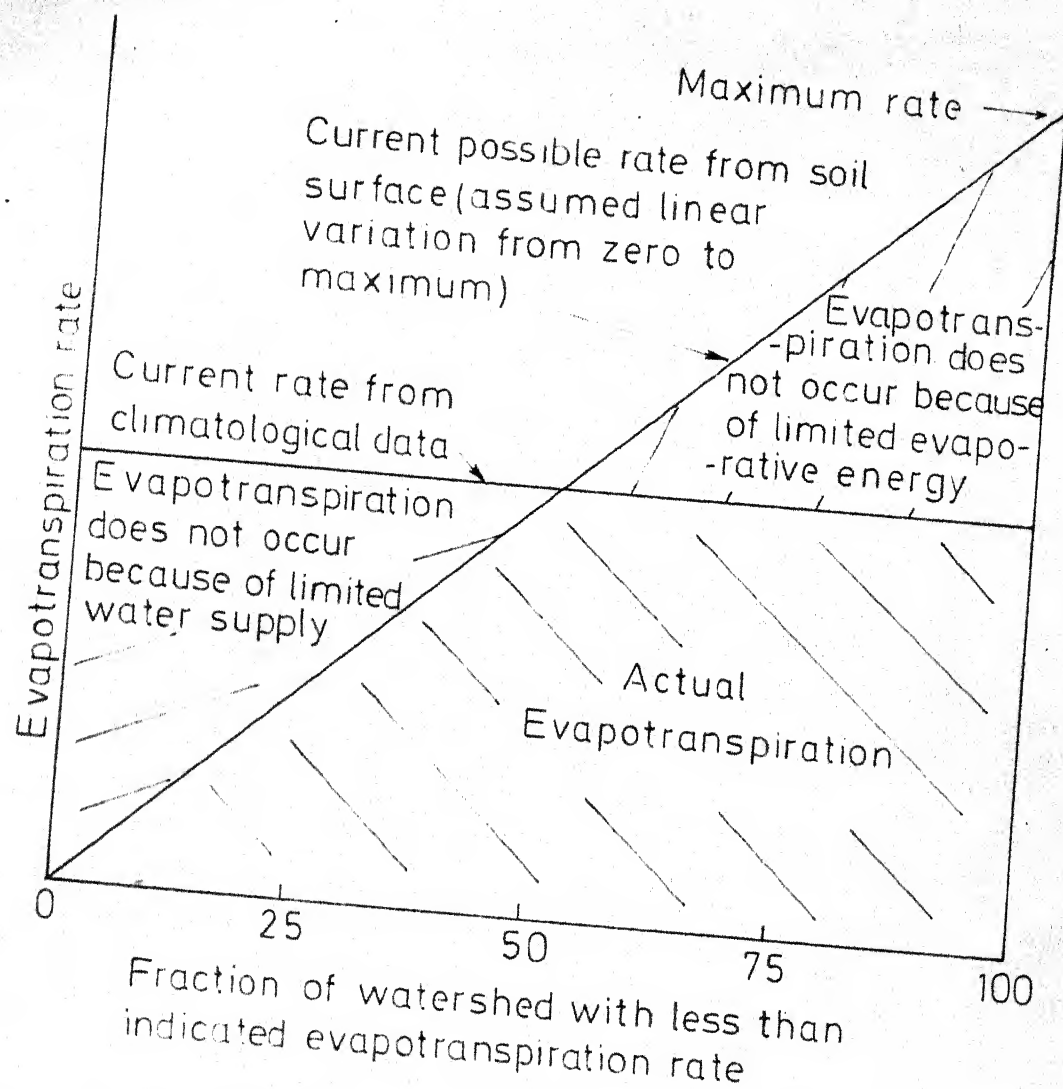


FIG. 6 MODEL FOR ESTIMATING ACTUAL EVAPOTRANSPIRATION



$$CMIR = \frac{CONSTANT * SIAM * BMIR}{\text{function}(LZS/LZC)}$$

$$SIAM = \text{function}(SIAC)$$

$$CIVM = BIVF * \text{function}(LZS/LZC)$$

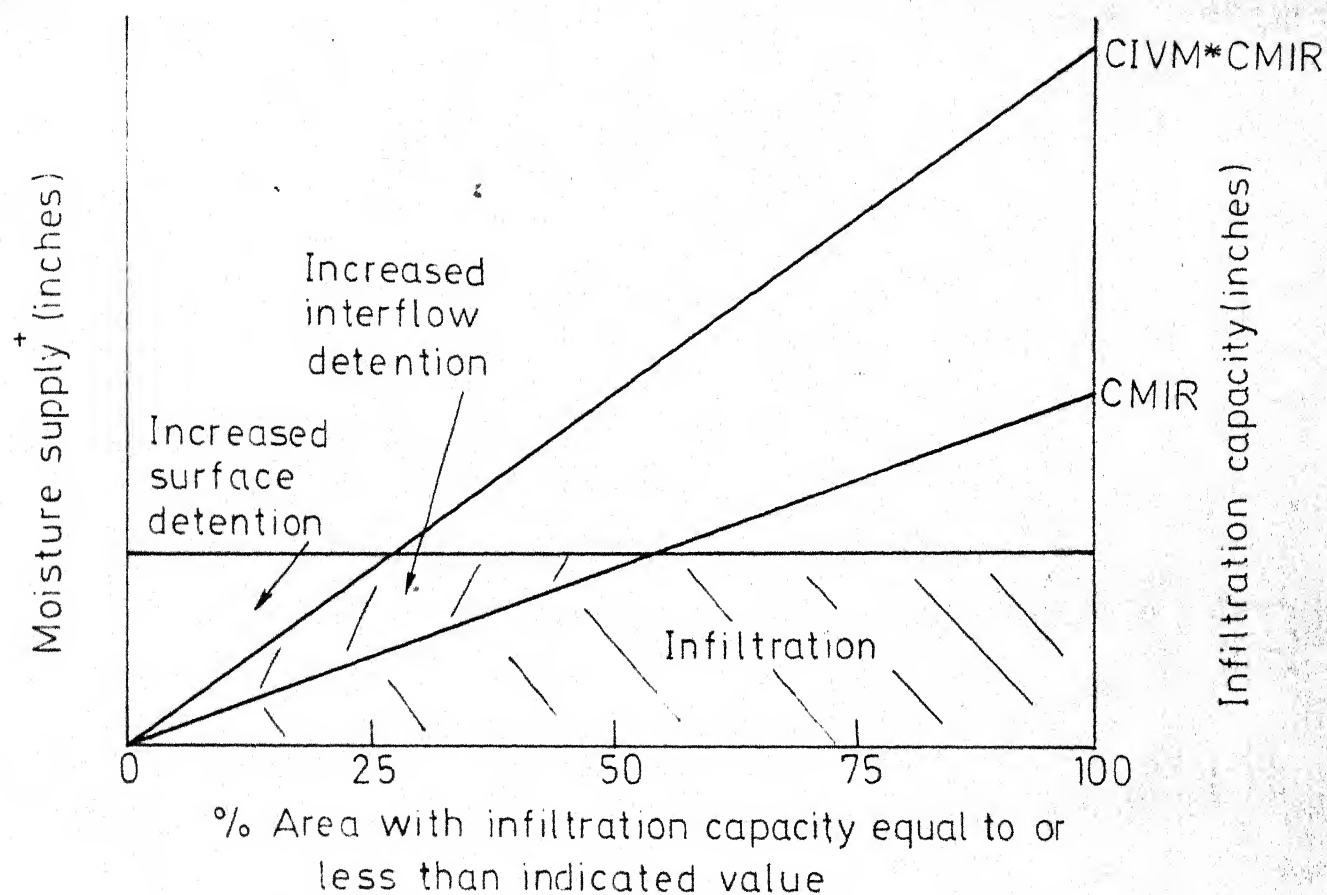


FIG.7 MODEL FOR ESTIMATING INFILTRATION CAPACITY

+ Rainfall passing through the upper zone plus holdover direct runoff



Increase in the value of BMIR reduces runoff during storm periods and later on increases runoff due to baseflow.

### 2.3.3 Surface Volume Parameter (BIVF):

It is an index controlling the time distribution and quantities of moisture entering the interflow. Increase in BIVF means more interflow by increasing the volume of CIVM. BIVF enters the streamflow simulation through the equation,

$$\text{CIVM} = \text{BIVF} \times 2^{(\text{LZS}/\text{LZC})} \quad (\text{Ref. Fig. 7})$$

In order to check negative interflow CIVM must be  $\geq 1$ . It is determined by the subroutine SETBIV.

### 2.3.4 Channel Routing Parameters (CSR, FSRX, NCTRI, CHCAP):

The subroutine SEMHRP estimates single best values for NCTRI and SRX for each of the 5 hydrographs (maximum 5) specified in the input data. Hydrograph NCTRI values are averaged in it to have single best value of NCTRI. The storage routing uses the equation,

$$O_2 = \bar{I} - \text{SRX} (\bar{I} - O_1)$$

where,

$O_2$  = routed outflow at the end of the time interval,

$\bar{I}$  = average inflow during the time interval,

$O_1$  = outflow at the beginning of the time interval,

SRX = storage routing index.

SRX for low flows is denoted by CSRX and SRX for flood flows is denoted by FSRX.

SETSRP estimates two channel routing parameters CSRX, FSRX. When the synthesized streamflow is less than one-half of CHCAP, CSRX is used for routing. If the synthesized flow exceeds twice CHCAP, FSRX is used. When the synthesized flow is in between these two SRX is interpolated from the equation,

$$SRX = CSRX + (FSRX - CSRX) \times \left( \frac{Q - 0.5 \text{ CHCAP}}{1.5 \text{ CHCAP}} \right)^3$$

where,

Q is the synthesized streamflow.

#### 2.4 Parameters Directly Estimated from the Watershed Characteristics:

1. AREA : Total area of the watershed in sq. miles,
2. FIMP : Fraction of watershed which is impervious and contributes its runoff directly into a stream.
3. FWTR : Fraction of total watershed covered by water surfaces,
4. VINTMR: Watershed interception volume storage capacity.

It is dependent upon the type and density of vegetation cover. A table to choose VINTMR is given below:

Table 1: Interception Values for Various Types of Cover. [4]

Watershed Cover	VINTMR (in)
Grass land	0.10
Moderate Forest cover	0.15
Heavy Forest cover	0.20

5. GWETF : It is a factor which when multiplied by the current rate of potential evaporation times the current ground water moisture storage gives an estimate of the current rate at which phreatophytes or swamp vegetation are drawing water from below the water table. For most of the basins this value is recommended to be zero [4].
6. SUBWF : Fraction of the moisture entering ground water storage which leaves the basin through sub-surface flow not measured by the stream gauge. Generally its value is zero.
7. OFSS : Average slope (in ft/ft) of the overland flow surfaces perpendicular to the receiving channel. Mean value is taken from randomly selected group of points on a topographic map.

To find out the discharge from the over land flow by Chezy-Manning formula this OFSS is used in the following equation:

$$q = \frac{1.486}{n} (y^{5/3}) (S^{1/2})$$

where,

q = discharge in cfs/ft.

y = depth of flow in ft.

S = slope of the surface in ft/ft (OFSS)

8. OFSL : Mean overland flow length in ft.  
It is the average distance that surface runoff in the watershed travels before reaching a channel. It is estimated as the reciprocal of twice the drainage density in sq.miles.
9. OFMN : Manning's roughness coefficient for overland flow on soil surfaces.
10. OFMNIS: Manning's roughness coefficient for overland flow over impervious surfaces.
11. CHCAP : Channel capacity - indexed to the outlet of basin: CHCAP may be estimated from hydraulic analysis of the profile and cross-section of the stream channel.
12. DIV : This is the daily flow diversion in cfs.  
Diversions into the streams are considered as positive.

## 2.5 Earlier Studies Using OPSET:

The original work on the development of Watershed Model started in 1959 at Stanford University in USA. Its name was given as Stanford Watershed Model (SWM). This model was developed through the versions of I, II, III and IV and was programmed for the digital computer in SUBALGOL language. D.L. James translated the model III into FORTRAN (G-Level) and simultaneously incorporated most of the features of model IV. This model was named as Kentucky Watershed Model (KWM). The

University of Kentucky in the year 1970 developed a self calibrating model named as OPSET. Then this model was tested in 20 watersheds most of which are rural. Liou [8] and Ross [4] gave **full** reports of the application of this OPSET models in the U.S.A.

## CHAPTER III

### IMPLEMENTATION OF OPSET PROGRAM

#### 3.1 Important Characteristics of the Program:

Important characteristics of the OPSET program are described below:

##### 3.1.1 Program Size and Memory:

OPSET is a very lengthy program. In all, about 2400 cards are needed to be punched (excluding data). Available core memory in IBM 7044 at IIT Kanpur is less than 32 K words (1 word = 6 bytes in IBM 7044 system). This memory is not sufficient for the OPSET program. On IBM 7044 two compilers are available viz. (i) WATFOR, (ii) FORTRAN. WATFOR compiler gives an extensive diagnostic report but execution is slow. Due to memory problem, and even for debugging purpose, the whole program could not be run at a time. Main program and each subroutine had to be fed separately for correcting the syntax errors. This did not solve the purpose. FORTRAN compiler ignores the undefined variables and some erroneous part of the program.

All these difficulties are overcome through the IBM 370/155 computer system at IIT Madras. Here WATFIV compiler which has a memory upto 512K bytes, has been used to

debug the program. The total memory requirement with one set of data is 250 K (bytes) (1 word on IBM 370/155 system equals 4 bytes).

### 3.1.2 Computer Time:

In IBM 370/155 system through WATFIV compiler with one year's data and all the options, computer time needed is 15 minutes (compilation and execution). This implies that IBM 7044 will take more than one hour to do the same job, because IBM 370/155 compiles and executes respectively eight and four times faster compared to IBM 7044/1401 system at IIT/Kanpur.

### 3.1.3 TRIPS:

The program is divided into three portions. In execution of the first portion 6 variables are taken into account. In the execution of the second portion other variables are considered. In the final step ~~all the~~ variables are taken together to give final synthesis. Execution of ~~each~~ of these portions is called a TRIP. First TRIP gives the optimized values of LLC, BMIR, SUZC, ETLF, BUZC and SIAC. In addition to these values, two other parameters BIVF and LZS are also obtained. The second TRIP starts working when the above values are optimized. In this TRIP the other six parameters CSRX, FSRX, NCTRI, CHCLF, IPRC, BPRC are optimized. Here the parameter values of the first TRIP remain~~s~~ unaltered. In the third TRIP all the parameter values taken together give the final run with the simulated flow.

### 3.1.4 Language:

The OPSET program is written in FORTRAN language. In this program one subroutine READ is used to read data in free format. But this subroutine is not readily available with us. READ subroutine is therefore replaced by the formatted READ statements.

### 3.2 Modifications:

#### 1. Water Year.

In the United States the water year is counted from the 1st October of the one year to the 30th September of the next year. In this study it is taken from the month of June and is modified accordingly.

#### 2. Evaporation Estimates:

In the test data of the OPSET program the evaporation is taken as the total evaporation in a year in inches and through the subroutine EVPDAY the daily values were calculated. In the present study the 10 daily average values of evaporation are used.

#### 3. Flood Peaks:

The flood peaks data for the watershed, used in the present work, are not available. These values are, hence, interpolated from the stream flow data.



### 3.3 Addition and Alterations:

To take care of the nonavailability of some data prescribed for the program and to work with the program in a different computer system, some necessary changes have been made. These are described below:

1. All the evaporation data available in the study are in mm, but the OPSET program uses them in inches. Through the following statements the evaporation data in mm are changed to inches,

```
990 DPET (KRD) = 0.03937 *DPET (KRD)
```

```
991 DPET (KRD) = 0.03937 *DPET (KRD)
```

2. In the original program the following statements were used to read the recorded stream flow for one year.

```
118 DAY = 274
```

```
119 CALL REAL (DRSF (DAY))
```

```
CALL DAYNXT (DAY,DPY)
```

```
IF (DAY.NE.274) GO TO 119
```

It is necessary to change the above statements as in the present case the first day of a water year is the 152 nd day of the calender year and not the 274th day as stated in the program. The following statements are, therefore, introduced.

```
118 DAY = 274
```

```
READ 1000, (DUM(J),J = 1, DPY)
```

```
PRINT 1000, (DUM(J), J = 1, DPY)
```

```
ISEQ = 1
```

```

119  DRSF (DAY) = DUM (ISEQ)
      ISEQ = ISEQ + 1
1000  FORMAT (13F6.1)
      CALL DAYNXT (DAY,DPY)
      IF (DAY,NE.(396-DPY)) GO TO 119

```

Here one dummy array DUM (J) is introduced. June 1 data is read as October 1 data. But these two dates differ in a year by 122 days, so the last line in the above statement 274 was replaced by 396-DPY.

3. The following statements are given in the main program of OPSET.

```

      DO 126 KRD = 1, NSGRD
      CALL READ (ISGRD)
126  CALL READ (DRSGP (ISGRD))
C    READ RECORDING RAIN GAGE HOURLY TOTALS
127  CALL READ (IVBG, YEAR, MONTH, DATE, CN)
C    PUNCH NO NUMBERS AFTER CN ON YEAR.EQ.98 CARD
      IF (YEAR.GE.98) GO TO 130
      HRF = 12* (CN-1) + 1
      HRL = 12* (CN-1) + 12
      DAY = MEDCY (MONTH) + DATE
      DO 128 HOUR = HRF, HRL
128  CALL READ (DRHP (DAY, HOUR))
      IF (DPY.NE.366.OR.MONTH.NE.2.OR.DATE.NE.29)GO TO 127

```

he above statements are changed to the following form for seasons mentioned above.

```

DO 126 KRD = 1, NSGRD
  READ 500, ISGRD
  READ 103, DRSGP (ISGRD)
126  DRSGP (ISGRD) = 0.03937 * DRSGP (ISGRD)
C   READ RECORDING RITE GAGE HOURLY TOTALS
127  READ 500, IWBG, YEAR, MONTH, DATE, CN
C   PUNCH NO NUMBERS AFTER CN ON YEAR.EQ.98 CARD
      IF (YEAR.GT.98) GO TO 130
      HRF = 12 * (CN-1) + 1
      HRL = 12 * (CN-1) + 12
      DAY = MEDCY (MONTH) + DATE + 122
      IF (DAY.GT.DPY) DAY = DAY-DPY
      DO 2000 IJK = 1,12
      IF (DAY.GT.MEDCY (IJK)) GO TO 2000
      MONTH = IJK - 1
      GO TO 2050
2000 CONTINUE
2050 CONTINUE
      READ 1003, (DRHP (DAY, HOUR), HOUR = HRF, HRL)
      DO 1291 HOUR = HRF, HRL
1291 DRHP (DAY, HOUR) = 0.03937 * DRHP (DAY, HOUR)
1003 FORMAT (12F 5.2)
      IF (DPY.NE.366.OR.MONTH.NE.2.OR.DATE.NE.29) GO TO 127
      DO 129 HOUR = HRF, HRL
Other alterations are mainly the changes in the FORMAT statements
and corrections of some printing errors in the OPSET program.
These are not mentioned here.

```

### 3.4 Time Spent on Collecting the Data and Implementing OPSUT:

The collection of relevant data, required for this program, constitute a large portion of the present work. Collection of data was started first in September 1974 and ultimately all the data could be collected from different places by the end of June 1975. Punching and correcting of the program started long before and ultimately in July 1975 the program was in perfect working condition. Only after that the work on the basic objective i.e. to use OPSUT for quantifying an Indian watershed, could be started. The work has been finally completed in October, 1975.

### 3.5 Factors Affecting the Efficiency of the Program:

1. Due to heterogeneous properties in the large watersheds it is very difficult to correlate the model parameters with watershed character. Watershed should be small enough to be homogeneous to minimise this difficulty.
2. The basin area should not be very large.
3. One run of OPSUT program takes a large amount of computer time and the computer expense is high. So for economic reasons it is desirable to use OPSUT for as few years as possible.
4. Two factors cause the variation of the parameter value for different water years. These are (i) differences in the pattern of deviation from year to year between gauge and watershed rainfalls and (ii) the differences in the pattern of the stream flows among the years.

## CHAPTER IV

### MODELING OF THE INDIAN BASIN AND THE RESULTS

#### 4.1 Description of the Basin.

The basin is bordered by two canals on two sides (Fig. 8). The whole area of the basin is more or less flat. The climate is temperate during hot summer months from May to September. Thereafter air becomes drier and cooler every day. Hoarfrost is common in January and February. For few nights in the year the ground temperature falls below  $0^{\circ}\text{C}$ . Average mean monthly maximum and minimum temperatures vary between  $60^{\circ}\text{F}$  to  $110^{\circ}\text{F}$  and  $35^{\circ}\text{F}$  to  $80^{\circ}\text{F}$  respectively. Northeast part of the area receives more than 50 inches (1270 mm) of rainfall annually and the southwest part receives between 15 inches to 20 inches (381 mm to 508 mm). This area has been formed of alluvial deposits brought by the rivers. Some part is formed of clay, hard clay or clay mixed with kankar at the top.

#### 4.2 Data Availability:

##### 4.2.1 Measurable Watershed Data:

The test data for the year 1956 for the basin Woodcock at London, Ky. USA are available with us. The OPSWT program is first run with this set of data.

Scale 0 4 8 12 Miles

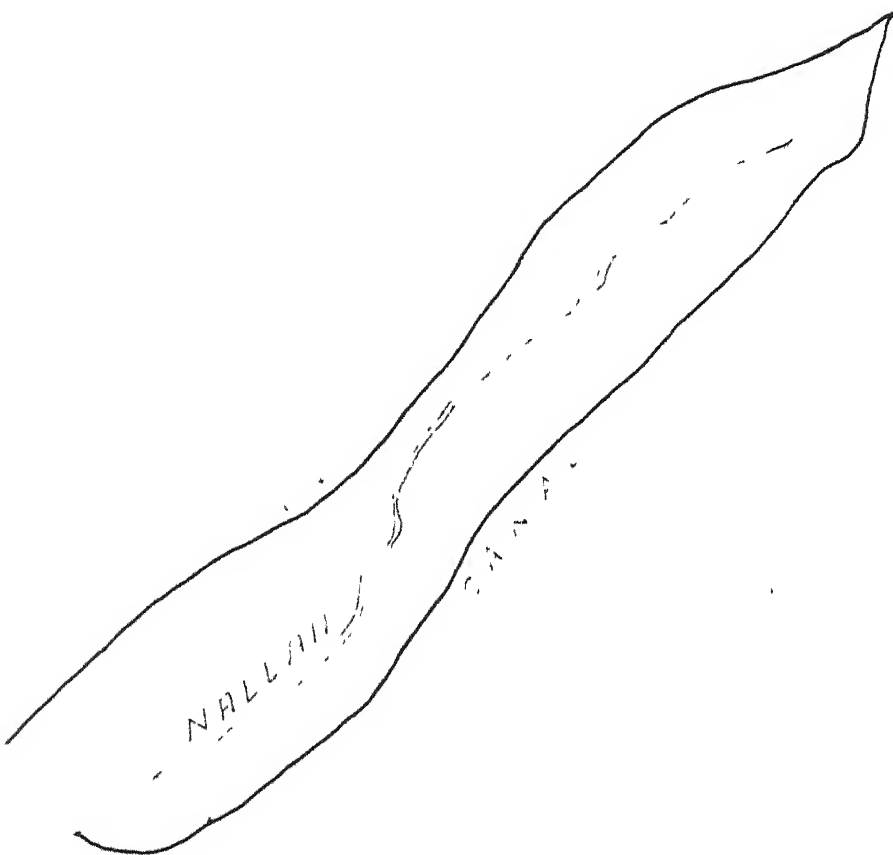


FIG 8 PLAN OF THE BASIN

For the basin in this study the following data were measured as accurately as possible. The description of all these are presented in Chapter 2.

1. AREA:

The maximum value of this is 650 sq.miles. The streamflow data were obtained from different places along the stream in different years. The areas under considerations are also different.

2. FIMP:

The impervious part of the area is significantly small. This value has been taken as 0.0005.

3. FWTR:

There is no lakes or swamps inside the area. Hence this value is taken as zero.

4. VINTMR:

No forest is observed inside the basin. The value of VINTMR is taken from the Table 1 (Chapter II) as 0.10.

5. GWETF:

As a significant number of phreatophytes or swamps are not known to exist inside the area, this value is taken as zero.

6. SUBWF:

It is assumed that no water leaves the basin through sub-surfaceflow not measured by the stream gauge after entering into the ground water storage from the surface. This value is, therefore, taken as zero.

## 7. OFSS:

This is obtained from the average of the measurements at randomly selected points on the basin. 4 measurements are taken from which the average is calculated as described below:

<u>Measurement No.</u>	<u>Slope (in ft/mile)</u>
1	5
2	2
3	10
4	5

Average slope = 5.5 ft in 1 mile  $\approx$  0.001 ( = 0.1 percent)

## 8. OFSL:

OFSL can be estimated in different ways. In this study, it is represented as the reciprocal of twice the drainage density (obtained by dividing total lengths of all the streams within the watershed in miles with the total area of the watershed in sq.miles). The calculation is shown below.

Total area of the watershed = 650 sq.miles

Total length of all the streams  
inside the watershed = 456.0 miles

Hence, the drainage density =  $\frac{456.0}{650.0} = 0.70$

OFSL =  $\frac{1}{2 \times (\text{drainage density})} = \frac{1}{2 \times 0.70}$

= 0.715 miles = 3780 feet



## 9. OFMN:

This value is taken from the table given below:

Table 2: Manning's Roughness Coefficient for Overland Flow for Various Surface Types [9]

Watershed Surface	Manning's n
Smooth Asphalt	0.013
Concrete (Trowel finish)	0.013
Rough Asphalt	0.016
Concrete (unfinished)	0.017
Smooth Earth	0.018
Firm Gravel	0.020
Cemented Rubble Masonry	0.025
Pasture (Short grass)	0.030
Pasture (High Grass)	0.035
Cultivated Area (Row Crops)	0.035
Cultivated Area (Field Crops)	0.040
Scattered Brush, Heavy Weeds	0.050
Light Brush and Trees (Winter)	0.050
Light Brush and Trees (Summer)	0.060
Dense Brush (Winter)	0.070
Dense Brush (Summer)	0.100
Heavy Timber	0.100

OFMN is taken for the basin as 0.035.

## 10. OFMNIS:

This value is also taken from the above table. For the present study it is taken as 0.018.

## 11. CHCAP:

The size of the channel at the gauging point may not be the size of the channel system as a whole. This can be measured from the hydraulic analysis of the profile and the cross section of the stream channel. Another method is to measure the gauge height of the bankful flow from the topographic map and then to read the CHCAP value directly from the stream gauge rating table. In this study CHCAP is indexed to the outlet of the basin and is taken as more than the measured maximum discharge.

## 12. DIV:

There is no flow diversion into or out of the stream and hence this value is taken as zero for the watershed in the study.

### 4.2.2 Meteorological Data:

#### 1. Evaporation Data:

Pan evaporation data are available for one station near the basin. Evaporation data are recorded with mesh covered fixed point gauge, class 'A' pan evaporimeter. These values were in millimeters and are converted to inches by multiplying with 0.03937.

#### 2. Pan Coefficients:

In this study these values are taken from the table given in Ref. 10. Starting from the month of January upto December, these values are 1.00, 1.00, 0.90, 0.75, 0.70, 0.70, 0.75, 0.90, 0.95, 0.90, 1.00 and 1.10.

### 3. Daily Hourly Precipitation Data:

These are recorded for one rain gauge station near the basin by a self recording rain gauge. These values are obtained again in mm and were converted to inches.

### 4. Daily Rainfall Data:

Daily rainfall data are also collected from an ordinary rain gauge station inside the basin. This raingauge is called in the program as the secondary rain gauge. The values obtained in mm were converted to inches.

Evaporation, hourly rainfall, daily rainfall and discharge data are collected for a few years. All the data are not available for the same place inside the basin. Two years data have been run but it is found that only in one particular year the rainfall data is in consistence with the discharge data.

### 5. Stream Flow Data.

This data is collected from the drainage nallah of the basin. Discharge data are not available for the basin for the same place for different years. These are available in different location in different years.

The basin is approximately rectangular in size and so the area covered by each stream gauge station is taken as linearly proportional to the distance of the stream gauge from the farthest end of the basin.

4.3 Simulation Analysis:

4.3.1 Initialization of Parameter Values:

OPSDI optimizes 13 parameters altogether. These are, LZC, BMIR, SUZC, ETLF, BUZC, SIAC, BIVF, BFRC, IFRC, CSRX, FSRX, ICTRI, CHCAP.

The following are the initial values of first six parameters inside the program.

Table 3: Initial Values of Parameters (Ref. 8, p. 33).

Starting Values			
Parameter	Low	Middle	High
LZC	2.00	12.00	30.00
BMIR	0.20	1.20	4.00
SUZC	0.30	1.30	4.00
ETLF	0.05	0.25	0.60
BUZC	0.20	1.50	5.00
SIAC	0.30	0.90	4.00

For the consistent estimate of reasonable parameter values the medium starting values worked best because they gave the best chance of being close to the final estimate and less chance to produce out-of-range adjusted values which may cause the program to stop before the optimum point is reached (Ref. 8, p. 34).

The initial values of the other parameters are as follows:

BIVF = 0.0 , FSRX = CSRX = SRX = 0.98

IFRC = 0.1 , BFRC = 0.9

#### 4.3.2 Control Options:

##### 1. CONOPT:

The OPSET program has the control options, expressed by CONOPT (1), CONOPT (2) and CONOPT (3).

CONOPT (1) = 0, if daily evaporation data are used.  
 = 1, if evaporation is read by 10 day period.  
 = 2, if annual evaporation is read and the subroutine EVPDAY is used.

CONOPT (2) = 0, if stream routing is to be done with 15 minutes time interval.  
 = 1, if stream routing is to be done with hourly time interval.

CONOPT (3) = 0, if no change in WSG or SGRT occur during the water year.  
 = 1, if storage gauge was moved during the water year.

In the test data CONOPT (1), CONOPT (2) and CONOPT (3) were taken as 2, 0 and 1 respectively. For the Indian data in this study these are taken as 1,1, and 0.

##### 2. MNRC, NFTR, and NLTR:

These are another set of control options which are given below:

MNRC = Minimum number of rough cycles to be made.  
 NFTR = Number of first trip to be run for a given year.  
 NLTR = Number of last trip to be run for a given year.

In all the cases, the values of MNRC, NFTR and NLTR are taken as 12, 1 and 3 respectively.

#### 4 Output Parameters Using the Test Data:

Test data [4] have been run through the OPSET program. Comparative study of these output parameters and that given in the report [3] is given in the following table.

Table 4: Comparison of Obtained Parameter Values with those given in the Ref.. 8.

Sl. No.	Parameter	Value given in the report	Value obtained from the program
1	LZC	11.14	11.76
2	BMIR	4.23	4.99
3	SUZC	0.65	0.65
4	BTLE	0.15	0.15
5	BUZC	1.04	1.09
6	SIAC	0.45	0.45
7	BIVP	0.00	0.00
8	CBRX	0.935	0.939
9	FORX	0.935	0.939
0	WCTRI	3.	3
1	IFRC	0.10	0.10
2	BPEC	0.895	0.894
3	CHCAP	100.0	100.0

In addition, the LZS value found in the report to be 38 and that obtained from the program is 8.83.

The synthesized and the recorded monthly flows and peak hydrographs are compared and shown in Table 5 and Table 6 respectively on the other pages.

Table 5: Comparison of Recorded and Synthesized Monthly flows for the Test Data.

Month	Recorded flow	Synthesized flow
October 1955	13.5	6.6
November 1955	11.8	8.2
December 1955	21.3	22.3
January 1956	63.9	107.4
February 1956	779.8	719.9
March 1956	469.4	451.4
April 1956	465.1	456.9
May 1956	160.5	78.6
June 1956	28.3	30.0
July 1956	202.3	263.2
August 1956	51.9	49.5
September 1956	26.5	117.5
Yearly Total	2294.3 sfd	2311.5 sfd

Table 6: Comparison of Recorded and Synthesized Hydrograph Peaks for the Test Data.

Date	Recorded		Synthesized	
	Peakflow (cfs)	Time	Peakflow (cfs)	Time
Feb. 17, 1956	506.0	11 PM	458.4	6.15 AM
Mar. 14, 1956	264.0	6 AM	213.1	6.00 AM
Apr. 6, 1956	133.0	10 AM	109.3	9.15 AM
Apr. 15, 1956	227.0	9 AM	355.7	8.30 AM

From the results shown in the preceding tables, it is evident that the model has been implemented with reliable accuracy. Here the lowest value of SSQM = 3.69

Obtaining fairly accurate results with the test data the model was then applied to an Indian basin. The following are the results obtained for the basin.

Table 7: Recorded and Synthesized Stream Flow For the Year 1971-72.

Months	Recorded	Synthesized
June	20.0	182.4
July	1306.0	2849.6
August	12460.0	9817.2
September	983.0	585.9
October	0.0	15.6
November	0.0	0.5
December	0.0	0.0
January	0.0	0.1
February	0.0	2.2
March	0.0	0.2
April	0.0	0.3
May	0.0	0.0
Yearly Total	14769.0 sfd	13454.0 sfd

Table 8: Comparison of Recorded and Synthesized Hydrograph Peaks for the Year 1971-72.

Date	Recorded		Synthesized	
	Peakflow (cfs)	Time	Peakflow (cfs)	Time
July 30	110.0	12 AM	121.0	0.15 AM
August 5	1950.0	12 AM	1898.8	1.00 AM
August 28	480.0	12 AM	122.8	0.15 AM

Lowest SSQM = 2.674



Table 9: Recorded and Synthesized Streamflow for the year 1969-70.

Months	Recorded Flow	Synthesized Flow
June 1969	0.0	6.0
July 1969	3416.0	634.5
August 1969	5850.0	11171.9
September 1969	2191.0	3464.9
October 1969	0.0	337.4
November 1969	0.0	41.0
December 1969	0.0	11.8
January 1970	0.0	8.8
February 1970	0.0	19.7
March 1970	0.0	12.0
April 1970	0.0	1.5
May 1970	0.0	1.4
Yearly Total	11457.0 sfd	15710.9 sfd

Table 10: Recorded and Synthesized Hydrograph Peaks for the Year 1969-70

Date	Recorded		Synthesized	
	Peak flow (cfs)	Time	Peak flow (cfs)	Time
29th July '69	425.0	12 AM	--	--
16th Aug. '69	340.0	12 AM	617.7	9.15 AM
13th Se t. '69	140.0	12 AM	123.2	0.15 AM

Lowest SSQM = 86.4999

Table 11: Optimum Parameter Values Obtained for an Indian Basin.

Parameter	Year 1969	Year 1971
LZC	12.0	2.3382
BMIR	--	11.6108
SUZC	1.3	3.0
ETLF	0.092	0.1793
BUZC	1.5	0.2761
SIAC	4.0	3.6
BIVF	0.0	0.0
BPRC	0.9267	0.8884
IFRC	0.10	0.10
CSRX	0.9950	0.90
FSRX	0.9950	0.90
NCPRI	47	25
CHCAP	2500	2000

Table 12: Recorded Flows for Test Data at Wood Creek, London, Ky, USA, 1955-56.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
1	0.4	0.3	0.3	0.5	5.7	8.6	4.0	5.6	3.2	8.7	4.7	3.5
2	0.4	0.3	0.5	0.5	20.0	8.6	5.4	35.0	1.6	1.2	4.3	1.2
3	0.3	0.3	1.6	0.5	36.0	11.0	7.1	22.0	1.5	0.8	3.7	0.7
4	0.3	0.3	3.0	0.4	47.0	9.2	19.0	12.0	1.3	0.7	3.7	0.7
5	0.3	0.3	1.5	0.4	22.0	8.2	9.8	9.2	1.2	4.7	2.9	0.6
6	0.3	0.3	1.0	0.4	35.0	7.6	50.0	7.9	1.1	1.8	2.7	6.1
7	1.8	0.3	0.9	0.4	20.0	26.0	30.0	7.0	0.9	1.1	2.7	2.1
8	0.6	0.3	0.7	0.4	12.0	34.0	17.0	5.2	0.9	0.9	2.0	1.2
9	0.4	0.2	0.7	0.3	9.5	19.0	12.0	4.8	0.9	1.0	1.6	0.8
10	0.4	0.3	0.6	0.4	7.9	13.0	9.8	4.2	0.8	0.9	1.5	0.7
11	0.3	0.3	0.6	0.4	13.0	10.0	8.2	3.8	0.7	0.6	1.6	0.6
12	0.3	0.2	0.5	0.4	10.0	11.0	7.0	3.4	0.7	0.5	1.3	0.6
13	1.4	0.2	0.5	0.3	9.2	15.0	6.2	3.0	0.7	11.0	1.3	0.5
14	0.6	0.2	0.5	0.3	13.0	103.0	7.2	2.8	0.6	14.0	1.4	0.4
15	0.5	0.3	0.5	0.3	17.0	35.0	94.0	2.8	0.6	3.9	1.2	0.5
16	0.4	0.3	0.4	0.4	14.0	27.0	59.0	2.6	0.5	8.6	1.1	0.5
17	0.4	0.3	0.4	0.3	103.0	18.0	29.0	2.2	0.5	6.6	0.9	0.4
18	0.4	0.3	0.6	0.3	143.0	16.0	17.0	2.1	1.4	4.7	0.9	0.4
19	0.4	1.1	0.6	2.0	44.0	12.0	12.0	2.0	1.8	3.5	0.9	0.4
20	0.3	0.4	0.5	0.7	25.0	9.8	9.2	1.8	0.9	5.8	2.0	0.4
21	0.3	0.3	0.5	0.6	16.0	8.9	7.6	1.5	1.1	6.5	1.5	0.4
22	0.3	0.3	0.5	0.6	12.0	7.6	7.0	1.4	0.9	2.7	1.2	0.4
23	0.3	1.9	0.5	0.6	10.0	6.8	6.5	1.4	0.6	15.0	1.0	0.6
24	0.3	0.6	0.5	0.5	35.0	7.6	5.6	1.3	0.5	22.0	0.9	0.5
25	0.3	0.5	0.5	0.5	39.0	6.2	4.8	1.2	1.3	18.0	0.9	0.4
26	0.3	0.4	0.5	0.5	24.0	5.6	4.4	1.2	0.5	14.0	0.8	0.4
27	0.3	0.4	0.4	0.5	16.0	5.1	4.0	1.3	0.4	10.0	0.8	0.4
28	0.3	0.3	0.4	0.6	12.0	5.9	3.6	3.6	0.4	8.6	0.8	0.4
29	0.3	0.3	0.4	11.0	9.5	5.1	3.4	3.6	0.4	11.0	0.7	0.4
30	0.3	0.3	0.6	33.0	-	4.4	4.3	2.0	0.4	7.8	0.7	0.4
31	0.3	-	0.5	5.9	-	4.2	-	1.6	-	5.7	0.7	-

Table 13: Synthesized Flow for Test Data at Wood Creek, London, Ky, USA, 1955-56.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep.
1	0.3	0.0	0.4	0.2	7.6	7.4	3.3	2.6	3.7	17.2	5.1	3.5
2	0.3	0.0	0.7	0.1	11.2	7.5	39.7	7.2	2.9	2.2	4.6	2.1
3	0.2	0.0	2.1	0.1	31.7	28.2	14.8	5.2	2.5	1.8	4.0	1.5
4	0.2	0.0	2.1	0.1	63.9	8.2	22.1	4.1	2.2	1.6	3.6	1.3
5	0.2	0.0	1.6	0.1	14.1	6.5	5.8	3.7	2.0	1.9	3.2	1.3
6	0.2	0.0	1.4	0.1	43.6	5.9	108.9	3.3	1.8	1.6	2.8	63.7
7	0.8	0.0	1.3	0.1	11.0	79.6	10.0	2.9	1.6	1.5	2.5	17.3
8	0.3	0.0	1.2	0.1	9.8	10.6	7.2	2.6	1.4	1.3	2.2	3.2
9	0.2	0.0	1.2	0.1	8.7	6.6	6.4	2.3	1.2	1.3	2.0	2.9
10	0.2	0.1	1.1	0.1	7.8	5.9	5.7	2.0	1.1	1.1	1.8	2.5
11	0.2	0.0	0.9	0.1	26.5	9.7	5.1	1.8	0.9	1.0	1.5	2.3
12	0.2	0.0	0.8	0.1	8.7	24.5	4.6	1.6	0.8	1.1	1.4	2.0
13	0.8	0.0	0.8	0.1	8.0	24.6	4.1	1.4	0.7	4.8	1.3	1.8
14	0.4	0.0	0.7	0.1	23.0	72.8	6.9	1.3	0.8	5.5	1.1	1.6
15	0.3	0.2	0.6	0.1	10.8	10.8	115.3	1.3	0.6	6.0	0.9	1.5
16	0.3	0.1	0.5	0.1	11.3	25.5	22.2	1.1	0.6	7.4	0.8	1.5
17	0.3	0.5	0.5	0.1	158.8	10.3	9.2	0.9	0.4	20.0	0.7	1.1
18	0.2	0.1	0.7	0.1	72.4	14.6	8.2	0.8	0.5	6.4	0.6	1.0
19	0.2	0.9	0.5	1.5	15.5	9.2	7.3	0.7	0.3	4.8	0.7	0.9
20	0.2	0.5	0.5	0.7	13.6	8.2	6.5	0.6	0.4	8.5	0.8	0.8
21	0.1	0.5	0.4	0.6	12.2	7.3	5.8	0.5	1.0	5.4	0.5	0.7
22	0.1	0.4	0.4	0.6	10.9	6.5	5.7	0.5	0.4	4.6	0.4	0.7
23	0.1	1.3	0.3	0.6	9.9	5.9	5.7	0.4	0.4	15.6	0.4	0.5
24	0.1	0.7	0.3	0.5	66.9	13.9	5.1	0.5	0.4	77.4	0.3	0.5
25	0.1	0.7	0.3	0.6	23.9	5.7	4.5	0.4	0.4	12.7	0.3	0.4
26	0.1	0.6	0.2	0.5	10.8	5.1	4.0	0.3	0.3	15.6	0.2	0.4
27	0.1	0.5	0.2	0.5	9.7	4.5	3.6	0.3	0.2	8.4	0.3	0.3
28	0.1	0.5	0.2	0.7	8.8	13.3	3.2	1.4	0.2	7.3	3.4	0.4
29	0.0	0.4	0.2	75.4	7.9	5.3	3.1	19.9	0.2	7.4	0.8	0.2
30	0.0	0.4	0.2	18.6	-	4.2	2.7	4.6	0.2	6.4	0.7	0.2
31	0.0	-	0.2	9.4	-	3.7	-	2.5	-	5.7	0.6	-

Table 15: Synthesized Daily Flows (Indian Basin, 1971-72)  
(cfs)

DAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.
1	0.0	70.8	101.0	70.2	2.3	0.1
2	0.0	90.6	841.9	62.3	2.0	0.1
3	0.0	185.8	1277.3	59.5	1.8	0.1
4	0.0	194.6	1115.2	55.9	1.6	0.1
5	0.0	208.3	724.9	49.6	1.4	0.0
6	0.0	207.0	591.2	44.1	1.3	0.0
7	0.0	192.5	517.5	39.2	1.1	0.0
8	0.0	175.5	458.5	34.8	1.0	0.0
9	0.0	158.1	407.0	30.9	0.9	0.0
10	0.0	141.4	361.5	27.5	0.8	0.0
11	0.0	125.9	321.0	24.4	0.7	0.0
12	0.0	111.9	285.1	21.7	0.6	0.0
13	0.0	99.4	253.4	19.2	0.6	0.0
14	0.0	88.3	224.9	17.1	0.6	0.0
15	0.0	78.4	199.7	15.2	0.5	0.0
16	0.0	69.6	177.4	13.5	0.4	0.0
17	0.0	61.8	190.9	12.0	0.4	0.0
18	0.0	71.6	174.1	10.6	0.4	0.0
19	0.0	79.5	154.6	9.4	0.3	0.0
20	0.0	70.6	137.3	8.4	0.3	0.0
21	0.0	62.6	121.9	7.4	0.2	0.0
22	0.0	55.6	108.3	6.6	0.2	0.0
23	0.0	49.4	96.2	5.9	0.2	0.0
24	0.1	70.7	85.4	5.2	0.2	0.0
25	2.3	69.0	75.8	4.6	0.2	0.0
26	20.8	68.8	79.9	4.1	0.1	0.0
27	30.7	65.9	113.9	3.7	0.1	0.0
28	29.2	58.5	112.8	3.2	0.1	0.0
29	28.4	94.8	100.2	2.9	0.1	0.0
30	27.8	128.1	89.0	2.6	0.1	0.0
31	-	113.8	79.0	-	0.1	-

Flows in the other months are all zero.

Table 16: Recorded Daily Flows (Indian Basin, 1969-70).  
(cfs)

DAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.
1	0.0	0.0	305.0	102.0	0.0	0.0
2	0.0	0.0	305.0	102.0	0.0	0.0
3	0.0	0.0	283.0	100.0	0.0	0.0
4	0.0	0.0	262.0	100.0	0.0	0.0
5	0.0	0.0	242.0	100.0	0.0	0.0
6	0.0	0.0	242.0	90.0	0.0	0.0
7	0.0	0.0	185.0	85.0	0.0	0.0
8	0.0	0.0	150.0	65.0	0.0	0.0
9	0.0	45.0	120.0	65.0	0.0	0.0
10	0.0	40.0	118.0	110.0	0.0	0.0
11	0.0	45.0	115.0	115.0	0.0	0.0
12	0.0	50.0	115.0	120.0	0.0	0.0
13	0.0	55.0	118.0	134.0	0.0	0.0
14	0.0	58.0	134.0	125.0	0.0	0.0
15	0.0	60.0	140.0	110.0	0.0	0.0
16	0.0	62.0	327.0	100.0	0.0	0.0
17	0.0	66.0	305.0	100.0	0.0	0.0
18	0.0	66.0	305.0	90.0	0.0	0.0
19	0.0	70.0	262.0	92.0	0.0	0.0
20	0.0	66.0	184.0	86.0	0.0	0.0
21	0.0	60.0	262.0	60.0	0.0	0.0
22	0.0	50.0	184.0	45.0	0.0	0.0
23	0.0	66.0	150.0	40.0	0.0	0.0
24	0.0	66.0	167.0	30.0	0.0	0.0
25	0.0	150.0	160.0	25.0	0.0	0.0
26	0.0	327.0	134.0	0.0	0.0	0.0
27	0.0	350.0	134.0	0.0	0.0	0.0
28	0.0	424.0	120.0	0.0	0.0	0.0
29	0.0	450.0	115.0	0.0	0.0	0.0
30	0.0	400.0	110.0	0.0	0.0	0.0
31	-	380.0	102.0	-	0.0	-

Flows in the other months are all zero.

Table 17: Synthesized Daily Flows (Indian Basin, 1969-70)  
(cfs)

DAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.
1	0.0	1.2	39.9	270.0	30.3	0.0
2	0.0	1.2	77.6	250.2	28.1	0.0
3	0.0	1.1	96.0	231.8	26.0	0.0
4	0.0	1.0	215.9	214.8	24.1	0.2
5	0.0	0.9	258.4	199.0	22.4	0.0
6	0.0	0.9	241.0	184.4	20.7	0.0
7	0.0	0.8	223.3	171.0	19.2	0.0
8	0.0	2.7	218.2	158.7	17.8	0.0
9	0.0	3.2	295.4	147.0	16.5	0.0
10	0.0	3.0	330.5	136.2	15.3	0.0
11	0.0	3.1	307.9	132.3	14.1	0.0
12	0.0	3.3	286.0	127.8	13.1	0.0
13	0.0	5.4	265.2	118.4	12.1	0.0
14	0.0	6.7	246.0	109.7	11.3	0.0
15	0.0	6.6	262.0	101.7	10.4	0.0
16	0.0	7.4	577.6	94.0	9.7	0.0
17	0.0	10.2	594.7	87.3	8.9	0.0
18	0.0	9.2	613.8	81.5	8.3	0.0
19	0.0	8.8	627.2	75.7	7.7	0.0
20	0.0	8.2	582.7	70.2	7.1	0.0
21	0.0	20.0	539.9	65.0	6.6	0.0
22	0.0	26.9	548.5	60.3	6.1	0.0
23	0.0	40.4	534.4	55.8	5.6	0.0
24	0.0	72.9	495.5	51.7	5.3	0.0
25	0.0	67.7	460.6	47.9	4.9	0.0
26	0.1	62.7	426.7	44.4	4.5	0.0
27	0.2	58.1	395.4	41.0	4.2	0.0
28	1.6	49.9	366.4	38.1	3.9	0.0
29	1.5	53.8	339.5	35.3	3.6	0.0
30	1.3	46.4	314.5	32.7	0.0	0.0
31	-	43.0	291.4	-	0.0	-

Flows in the other months are very negligible.

## CHAPTER V

### DISCUSSIONS AND CONCLUSIONS

#### 5.1 Discussion of the Results:

##### 5.1.1 SSQM:

SSQM is the sum of squares of deviations for 11 months and it is used to indicate which set of volume parameter values gives the best synthesis of flow volumes. The first month of the water year is excluded from this least square term because the flows in the first month are too dependent on unknown initial conditions. The final value of SSQM gives a reliable indication as to how best the parameters are synthesized with respect to the input data.

##### 5.1.2 Test Data:

After going through the results from the test data, it is observed that the optimized 13 output parameters are closely comparable with the reported values [8]. The recorded daily stream-flow and the synthetic flow, as shown in the Tables 12, 13 are also comparable. In addition, from Table 6, it is clear that peak hydrograph values also matched well. Hence the OPSET program is well implemented, in the computer system available with us. Monthly flows are compared in Fig. 9.

##### 5.1.3 Indian Data:

After analysing the output for 2 years for Indian data, the following observations can be made.



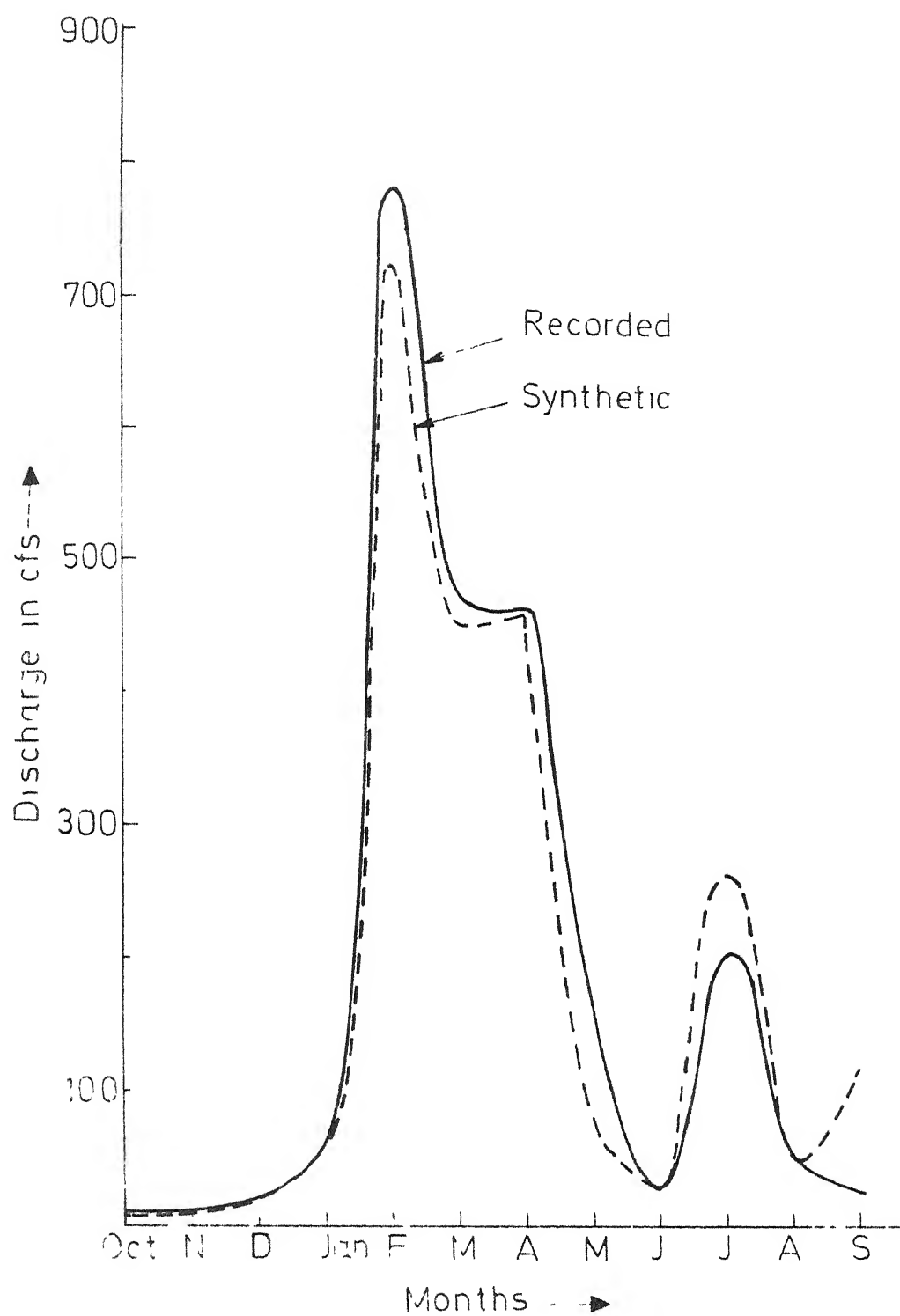


FIG. 1) TEST DATA - WOOD CREEK, USA, WATER YEAR 1956  
(MONTHLY FLOW)

Year 1969-70:

From the table 16,17, it is observed that the daily recorded stream flow did not match with the daily synthesized stream flow. Similarly the monthly flows and the yearly totals of recorded and synthesized stream flows have wide gap. Peak hydrograph values between the observed and the synthetic cannot be compared. Hence the parameter values obtained on the basis of this year data are not correct. SSQM value in this year is high. The daily recorded and synthesized flows are shown in Fig. 11.

Year 1971-72:

From the Figure 10 and the Tables 14 and 15 of the daily stream flow hydrograph and the monthly totals respectively for the observed and the synthesized values, it is seen that these two matched well. Again the recorded hydrograph peak values can be compared with the synthesized hydrograph peak values. The SSQM value is very low in this year. Hence the parameter values for the year 1971-72 are taken as the optimum parameters for the basin. These values are:

LZC = 2.338 , BMIR = 11.610 , SUZC = 3.00,  
 ETLE = 0.1793 , BUZC = 0.2761 , SIAC = 3.60,  
 BIVE = 0.0 , BFRU = 0.8884 , IFRC = 0.10,  
 CSRX = 0.90 , PSRA = 0.90 , NCTRI = 25 and  
 CHCAF = 2000.

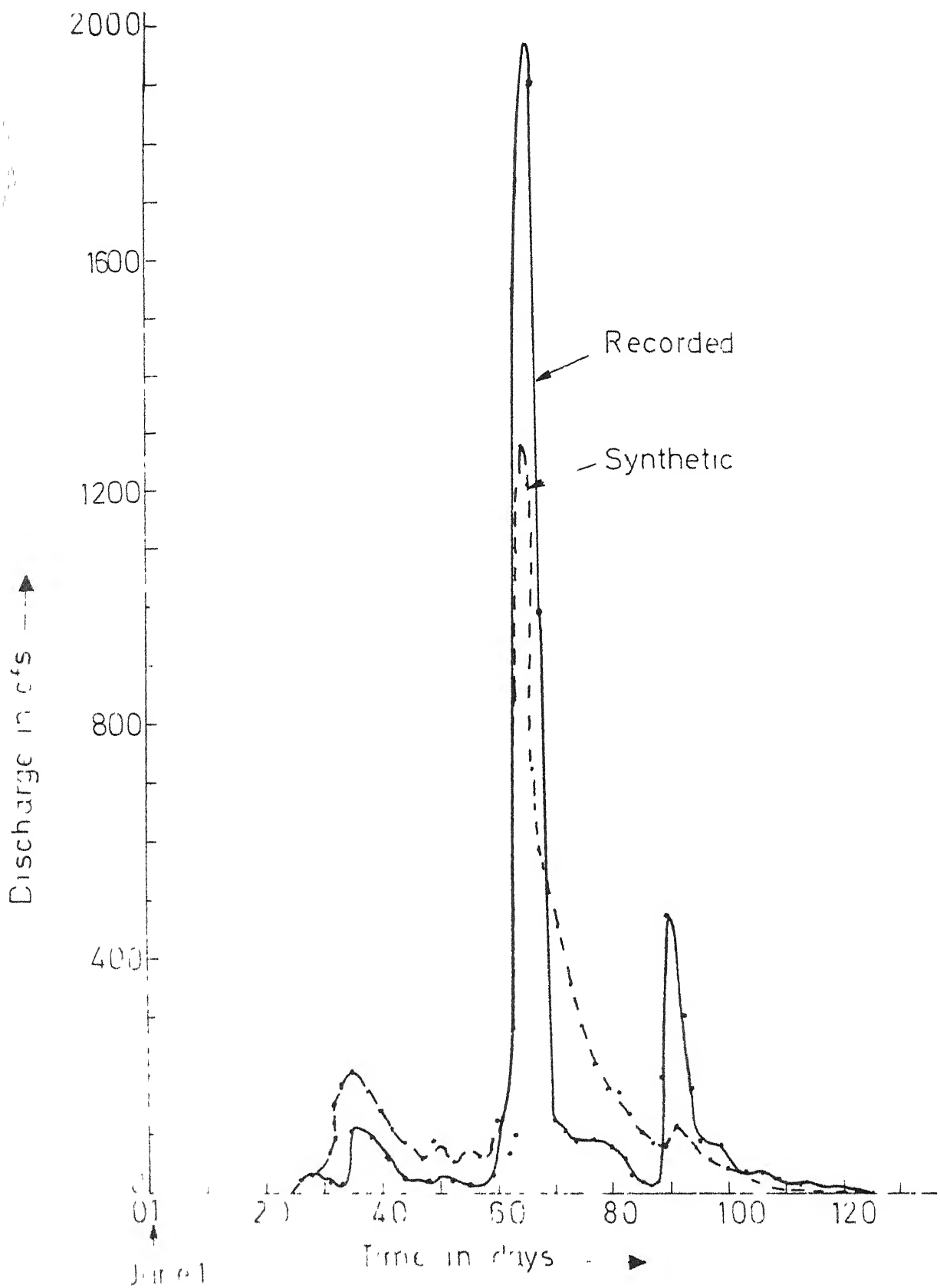


FIG. 10. RECORDED AND SYNTHESIZED DAILY FLOWS OF INDIAN BASIN WATER YEAR 1971-72

It is clear that the results obtained for the Indian basin are not really accurate. Also, the results from the different years are not equal to each other. This is basically due to the following factors.

- (i) All the rain gauge stations whose recorded hourly and daily rainfalls, used in the present work, are not situated within the basin. So the rainfall pattern fed to the program is different from the actual pattern.
- (ii) Streamflow records are not reliable. Some values are missing and some are not observed.
- (iii) Topographic sheet for the area is not available.
- (iv) Watershed area is large.
- (v) Unlike the test data for rainfall, the rainfall in the basin under study occur mainly for 3 months in a year.
- (vi) The peak flow discharge data are not available.
- (vii) The streamflow gauging points are different in different years.

However, the parameter values obtained from the data for the year 1971 are the better of the two. They can be taken as very good approximation for the parameters of the watershed. This can be inferred from the following reasons:

- (i) In the year 1971 the rainfall and streamflow patterns are comparable.
- (ii) SSQM value is very low in this year.

(iii) With days passing, the data availability also is more. The data which are not available for the preceding years are available for the year 1971. Hence, the results also can be considered better.

## 5.2 Conclusions and Scope of Further Studies.

Through the OPSET program very good prediction of annual streamflow and fairly good prediction of monthly streamflow are obtained. Flood hydrographs are simulated less accurately.

Natural phenomena being simulated are frequently too complex to permit an intricate analysis and to simplify these further research is necessary.

Measurable watershed parameters should be measured very accurately and the proper authorities should be well informed in advance to keep the necessary data for further studies. Peak flows are very much needed for estimating the channel routing parameters.

OPSET program should be applied in different watersheds varying in sizes, locations and climatological conditions.

Effect in the changes in the watershed such as urbanization and agricultural land use should also be studied through this program.

For larger watersheds, it is better to subdivide the total area into parts, each with its own set- of parameters,

and combine these results by stream routing.

Further detailed studies should be made to find out the ground water re-charge through this model.

## REFERENCES

1. Amorochio, J., and Hart, W.E., 'A Critique of Current Methods in Hydrologic System Investigations', Transactions: American Geophysical Union, Vol. 45, (June, 1964), pp. 307-321.
2. Ramaseshan, S., 'A Stochastic Analysis of Rainfall and Runoff Characteristics by Sequential Generation and Simulation', Ph.D. Thesis, Department of Civil Engg., University of Illinois, Urbana, 1964.
3. Bell, F.C., 'Short-Term Flood Forecasting with the Retention Model', WMO, Technical Note No. 92, 1969, pp. 193-207.
4. Ross, Glendon, L., 'The Stanford Watershed Model: The Correlation of Parameter Values Selected by a Computerized Procedure with Measurable Physical Characteristics of the Watershed', Lexington: University of Kentucky, Water Resources Institute, Research Report No. 35, 1970.
5. James, L., Douglas, 'An Evaluation of Relationships Between Streamflow Patterns and Watershed Characteristics Through the Use of OPSET: A Self-Calibrating Version of the Stanford Watershed Model', Lexington: University of Kentucky, Water Resources Institute, Research Report No. 36, 1970.
6. James, L. Douglas, 'Using a Digital Computer to Estimate the Effects of Urban Development on Flood Peaks', Water Resources Research, Vol. 1, (Second Quarter, 1965), pp. 223-233.
7. James, L. Douglas and Thompson, William O., 'Least Squares Estimation of Constants in a Linear Research Model', Water Resources Research, Vol. 6 (August, 1970), pp. 1062-1069.
8. Liou, Earnest Yuan-Shang, 'OPSET Program for Computerized selection of Watershed Parameter Values for the Stanford Watershed Model', University of Kentucky, Water Resources Institute, Lexington, Kentucky, Research Report No. 34, 1970.

9. Chow, Ven Te., 'Open Channel Hydraulics', McGraw-Hill, Book Company, Inc., 1959.
10. Venketaraman, S., and Arishnamurthy, V., 'Irrigation and Power' Journal, January 1973, pp. 59-66.
11. Linsley, Ray. K., Kohler, Max A., Paulhus, Joseph L.H., 'Hvdrology for Engineers', McGraw-Hill Book Company, Inc. 1958.
12. Viessman, Warren, Harbaugh, Perence, E., Knapp, John W., 'Introduction to Hydrology', Intext Educational Publishers, New York/London.



## APPENDIX

### COMPARISON OF ANNUAL RUNOFF CALCULATED BY OPSET METHOD WITH THAT BY AN APPROXIMATE METHOD

TEST DATA: Year 1956, Wood Creek, Ky, USA.

#### Approximate Method:

$$\text{Runoff} = \text{Rainfall} - \text{Evapotranspiration}$$

In this year of test data

$$\text{Rainfall} = 53.86 \text{ inches.}$$

$$\text{Evapotranspiration (Potential)} = 35.785 \text{ inches.}$$

$$\text{Annual Runoff} = (53.86 - 35.785) = 18.075 \text{ inches.}$$

$$\text{Total area of the watershed} = 3.89 \text{ square miles}$$

$$\text{Annual Run off} = \frac{3.89 \times (5280)^2}{12 \times 86400} \times 18.075 = 1920 \text{ sfd}$$

Net evapotranspiration calculated by OPSET program is  
29.094 inches.

$$\text{Hence Annual Runoff} = (53.86 - 29.094) = 24.766 \text{ inch.}$$

$$= \frac{3.89 \times (5280)^2}{12 \times 86400} \times 24.766 = 2582 \text{ sfd}$$

Annual Runoff calculated by OPSET = 2311.5 sfd.

It seems that the net evapotranspiration value gives the better result in Approximate method.

For Indian data the total annual evapotranspiration values always exceeded the net precipitation in the year and hence the above method could not be used. Khosla's method could not be applied due to non-availability of the value of the constant for the catchment under consideration.

SHM00000  
SHM00010  
SHM00020  
SHM00030  
SHM00040  
SHM00050  
SHM00060  
SHM00070  
SHM00080  
SHM00090  
SHM00100  
SHM00110  
SHM00120  
SHM00130  
SHM00140  
SHM00150  
SHM00160  
SHM00170  
SHM00180  
SHM00190  
SHM00200  
SHM00210  
SHM00220  
SHM00230  
SHM00240  
SHM00250  
SHM00260  
SHM00270  
SHM00280  
SHM00290  
SHM00300  
SHM00310  
SHM00320  
SHM00330  
SHM00340  
SHM00350  
SHM00360  
SHM00370  
SHM00380  
SHM00390  
SHM00400  
SHM00410  
SHM00420  
SHM00430  
SHM00440  
SHM00450  
SHM00460  
SHM00470  
SHM00480  
SHM00490  
SHM00500  
SHM00510  
SHM00520  
SHM00530

.....  
LISTING OF THE COMPUTER PROGRAMME  
.....

C COMPUTER PROGRAM ON HYDROLOGIC SIMULATION  
C OPSET  
C A SELF-CALIBRATING VERSION OF THE STANFORD WATERSHEDMODEL  
C BASIC LOGIC OF INNER LOOP BASED ON STANFORD WATERSHED MODELS III AND I  
C VERSION OF NOVEMBER 12, 1970  
C \*\*\*\*\*  
C \*  
C \*  
C \* IMPLEMENTED FOR THE SYSTEMS IBM 7044 AND IBM 370/155  
C \*  
C \*\*\*\*\*  
C IN THIS STUDY WATER YEAR STARTS FROM JUNE 1  
C DAY = 274 IN THE PROGRAMME IS TAKEN FOR JUNE 1  
C MONTHS IN THE TABULATED RECORDED AND SYNTHESIZED FLOWS ARE CHANGED  
C IN THE NEW FORMAT ALSO DATES SHOULD BE READ AS FOLLOWS  
C \*\*\*\*\* JUNE 1 AS JUNE 1 \*\*\*\*\*  
C \*\*\*\*\* JULY 1 AS JULY 2 \*\*\*\*\*  
C \*\*\*\*\* AUG 1 AS AUG 2 \*\*\*\*\*  
C \*\*\*\*\* SEPT1 AS SEPT1 \*\*\*\*\*  
C \*\*\*\*\* OCT 1 AS OCT 2 \*\*\*\*\*  
C \*\*\*\*\* NOV 1 AS OCT 30 \*\*\*\*\*  
C \*\*\*\*\* DEC 1 AS NOV 30 \*\*\*\*\*  
C \*\*\*\*\* JAN 1 AS DEC 30 \*\*\*\*\*  
C \*\*\*\*\* FEB 1 AS JAN 30 \*\*\*\*\*  
C \*\*\*\*\* MAR 1 AS MAR 1 \*\*\*\*\*  
C \*\*\*\*\* APR 1 AS APR 1 \*\*\*\*\*  
C \*\*\*\*\* MAY 1 AS MAY 2 \*\*\*\*\*

	DIMENSION BTRI(99), CONOPT(5), CTRI(99), DRGPM(366), DRHP(366,24),	SHM00540
1	DRSGP(366), DPET(366), DRSF(366), DSSF(366), EMGWS(12),	SHM00550
2	EMIFS(12), EMLZS(12), EMSIAM(12), EMUZC(12), EMUZZ(12),	SHM00560
3	EPCM(12), HBF(5), IDYB(5), IDYE(5), IHRB(5), IHRE(5), KPSH(5),	SHM00570
4	LSHA(5), MEDCY(12), MEDWY(12), RHPD(5), RHPF(5), RHPH(5)	SHM00580
	DIMENSION RSBBF(20), RSBD(20), RSBI(20), SBFRS(3,20)	SHM00590
6	,THSF(24), TITLE(20), TMBF(12), TMIF(12), TMNET(12), TMOF(12),	SHM00600
7	TMPET(12), TMPREC(12), TMRTF(12), TMSE(12), TMSTF(12),	SHM00610
8	TMSTFI(12), UHFA(99), XMPFT(12), DUM(368), SIFRS(3,20), SSR(5,170)	SHM00620
	LOGICAL LBMIR, LBUZC, LETLF, LLZC, LNPR, LRC, LSHA, LSHP	SHM00630
	INTEGER CN, CONOPT, DATE, DAY, DPY, EHSKD, HOUR, HRF, HRL, PDAY,	SHM00640
1	PRD, RHPD, RHPH, RSBD, SGMD, SGRT, SGRT2, TRIP, YEAR, YR1,	SHM00650
2	YR2	SHM00660
	REAL IFPRC, IFRC, IFRL, IFS, LZC, LZRX, LZS, LZSR, MNRD, NHPT	SHM00670
	DATA MEDCY/ 0, 31, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334 /	SHM00680
	DATA MEDWY/ 304, 334, 365, 31, 59, 90, 120, 151, 181, 212, 243, 273 /	SHM00690
C	SPECIFY NUMBER OF STATION-YEARS INCLUDED IN COMPUTER RUN	SHM00700
	NSYC = 0	SHM00710
	READ 500, NSYT	SHM00720
500	FORMAT(5I5)	SHM00730
100	NSYC = NSYC + 1	SHM00740
C	READ TITLE TO COMPUTER RUN	SHM00750
	READ (5,1) TITLE	SHM00760
1	FORMAT(20A4)	SHM00770
C	READ CONTROL OPTIONS	SHM00780
	READ 101, (CCNOPT(I), I=1,3)	SHM00790
101	FORMAT(3I2)	SHM00800
	READ 101, MNRC, NFTR, NLTR	SHM00810
C	READ BASIC TIME-AREA HISTOGRAM	SHM00820
	DO 102 KIA = 1, 99	SHM00830
	BTRI(KIA) = 0.0	SHM00840
102	UHFA(KIA) = 0.0	SHM00850
	READ 500, NBTRI	SHM00860
	READ 103, (BTRI(J), J=1, NBTRI)	SHM00870
103	FORMAT(8F10.5)	SHM00880
C	SET INITIAL CONDITIONS	SHM00890
	IFT = 1	SHM00900
	LRC = .TRUE.	SHM00910
	LLZC = .FALSE.	SHM00920
	LBUZC = .FALSE.	SHM00930
	LBMIR = .FALSE.	SHM00940
	LETLF = .FALSE.	SHM00950
	LNPR = .FALSE.	SHM00960
	IF(CCONPT(2) .EQ. 0 .AND. NBTRI .LE. 6) LNPR = .TRUE.	SHM00970
	KRC = 1	SHM00980
	KBRC = 0	SHM00990
	KFFC = 0	SHM01000
	SSSQM = 950.0	SHM01010
	SGRT = 0	SHM01020
C	READ FIXED PARAMETERS	SHM01030
104	READ 103, RMPF, CHCAP	SHM01040
	READ 103, RGPM, AREA, FIMP, FWTR	SHM01050
	READ 103, VINTMR, SUBWF, GWETF, OFSS, OFMN, OFMNIS, OFSL, DIV	SHM01060
		SHM01070

```

C  CALCULATE CONSTANTS SET BY FIXED PARAMETERS
    FPER = 1.0 -FIMP-FWTR
    IF(FPER .GT. 0.01) GOTO 105
    TPLR = 100.0
    FPER = 0.01
    GO TO 106
105 TPLR = (1.0-FWTR)/FPER
106 VWIN = 26.8888*AREA
    WCFS = 24.0*VWIN
    RHFC = 0.025/WCFS
    SSRT = SQRT(OFSS)
    OFRF = 1020.0*SSRT/(OFMN *OFSL)
    OFRFIS=1020.0*SSRT/(OFMNIS*OFSL)
    EQDF = 0.00982*(((OFMN*OFSL/SSRT)**0.6)
    EQDFIS = 0.00982*(((OFMNIS*OFSL/SSRT)**0.6)
    RGPM =RGPMB
C  READ WATER YEAR
    READ 101,YR1,YR2
    DPY = 365
    IF(MOD(YR2,4) .EQ. 0) DPY = 366
C  READ EVAPORATION DATA
    IF(CONOPT( 1) .NE. 1) GO TO 111
    READ 103,(DPET(KRD),KRD=274,360,10)
    DO 990 KRD=274,360,10
990  DPET(KRD) = 0.03937*DPET(KRD)
    READ 103,(DPET(KRD),KRD=1,273,10)
    PRINT 103, (DPET(KRD), KRD= 1,273,10)
    DO 991 KRD = 1,273,10
991  DPET(KRD) = 0.03937*DPET(KRD)
    DO 110 IDAY2=1,9
    DO 109 IDAY1= 274,360,10
    DAY= IDAY1 +IDAY2
109  DPET(DAY)= DPET(IDAY1)
    DO 110 IDAY1=1,273,10
    DAY=IDAY1+ IDAY2
    IF(DAY.GT. 273) GO TO 110
    DPET(DAY) =DPET(IDAY1)
110  CONTINUE
    DPET(366)=DPET(59)
    DPET(365) = DPET(363)
    DPET(364)= DPET(363)
    GO TO 113
111  IF(CONOPT( 1) .EQ. 2) GO TO 116
    DAY =274
112  READ 103,DPET(DAY)
    IF(DAY .EQ. 273) GO TO 113
    CALL DAYNXT(DAY, DPY)
    GO TO 112
113  READ 103,(EPCM(MONTH),MONTH=1,12)
    PRINT 103, (EPCM(MONTH) , MONTH=1,12)
    EPAET=0.0
    DO 115 DAY =1,DPY
115  EPAET =EPAET +DPET(DAY)
    IF(EPCM(6) .NE. 1.0) EPAET =0.7*EPAET

```

```

SHM01080
SHM01090
SHM01100
SHM01110
SHM01120
SHM01130
SHM01140
SHM01150
SHM01160
SHM01170
SHM01180
SHM01190
SHM01200
SHM01210
SHM01220
SHM01230
SHM01240
SHM01250
SHM01260
SHM01270
SHM01280
SHM01290
SHM01300
SHM01310
SHM01320
SHM01330
SHM01340
SHM01350
SHM01360
SHM01370
SHM01380
SHM01390
SHM01400
SHM01410
SHM01420
SHM01430
SHM01440
SHM01450
SHM01460
SHM01470
SHM01480
SHM01490
SHM01500
SHM01510
SHM01520
SHM01530
SHM01540
SHM01550
SHM01560
SHM01570
SHM01580
SHM01590
SHM01600
SHM01610

```



GO TO 117	SHM01620
PRINT 103, EPAET, MNRD	SHM01630
116 READ 103, EPAET, MNRD	SHM01640
EMAET = EPAET * (365.0 + MNRD) / 404.0	SHM01650
CALL EVPDAY(DPET, EMAET)	SHM01660
C READ DAILY FLOW DATA	SHM01670
117 DRSF(366) = 0.0	SHM01680
118 DAY = 274	SHM01690
READ 1000, (DUM(J), J=1, DPY)	SHM01700
PRINT 1000, (DUM(J), J=1, DPY)	SHM01710
ISEQ = 1	SHM01720
119 DRSF(DAY) = DUM(ISEQ)	SHM01730
ISEQ = ISEQ + 1	SHM01740
1000 FORMAT(13F6.1)	SHM01750
CALL DAYNXT(DAY, DPY)	SHM01760
IF(DAY .NE. (396-DPY)) GO TO 119	SHM01770
IF(DIV .EQ. 0.0) GO TO 122	SHM01780
DO 121 DAY = 1, DPY	SHM01790
IF(DRSF(DAY) .GT. DIV) GO TO 120	SHM01800
DRSF(DAY) = 0.0	SHM01810
GO TO 121	SHM01820
120 DRSF(DAY) = DRSF(DAY) - DIV	SHM01830
121 CONTINUE	SHM01840
122 WRITE(6, 2) (TITLE(KTA), KTA = 1, 20)	SHM01850
2 FORMAT(1H1, 25X, 20A4)	SHM01860
C WRITE DAILY FLOWS	SHM01870
CALL DAYSUM(DRSF, MEDCY, DPY, RATEFV, TMRTF)	SHM01880
WRITE(6, 3)	SHM01890
3 FORMAT(1H0, 42X, ' RECORDED FLOWS ')	SHM01900
CALL DAYOUT(DRSF, MEDWY, DPY)	SHM01910
WRITE(6, 4) (TMRTF(KWD), KWD = 1, 12), RATEFV	SHM01920
4 FORMAT(6X, 'TOTAL', 2X, 12F8.1, 2X, F10.1, 2X, 3HSFD)	SHM01930
C READ STORM HYDROGRAPH DATA	SHM01940
READ 510, NRHP, NHPT	SHM01950
PRINT 510, NRHP, NHPT	SHM01960
510 FORMAT(15, F10.5)	SHM01970
IF(NRHP .EQ. 0) GO TO 124	SHM01980
DO 123 KRD = 1, NRHP	SHM01990
READ 90, RHPD(KRD), RHPH(KRD), RHPF(KRD)	SHM02000
90 FORMAT(2I5, F10.5)	SHM02010
123 WRITE(6, 5) KRD, NHPT, RHPD(KRD), RHPH(KRD), RHPF(KRD)	SHM02020
5 FORMAT(/ / 5X, 'RECORDED HYDROGRAPH', I3 / 10X, 'HYDROGRAPH INTERVAL =',	SHM02030
1F5.2, 1X, 5HHOURS / 10X, 'CALENDAR DAY OF PEAK =', I5, 5X, 'HOUR OF DAY ='	SHM02040
2, I4, 5X, 'PEAK FLOW =', F8.1, 1X, 3HCFS)	SHM02050
C INITIALIZE PRECIPITATION DATA ARRAYS	SHM02060
124 DO 125 DAY = 1, 366	SHM02070
DRGPM(DAY) = RGPMB	SHM02080
DSSF(DAY) = 0.0	SHM02090
DRSGP(DAY) = 0.0	SHM02100
DO 125 HOUR = 1, 24	SHM02110
125 DRHP(DAY, HOUR) = 0.0	SHM02120
C READ AUXILIARY RAIN GAGE DAILY TOTALS	SHM02130
READ 500, NSGRD	SHM02140
IF(NSGRD .EQ. 0) GO TO 127	SHM02150

READ 510,SGRT,WSG	SHM02160
IF(CONOPT(3).EQ.1)READ 90,SGRT2,SGMD,WSG2	SHM02170
DO 126 KRD = 1,NSGRD	SHM02180
READ 103, DRSGP(ISGRD)	SHM02190
READ 500,ISGRE	SHM02200
126 DRSGP(ISGRD) = 0.03937*DRSGP(ISGRD)	SHM02210
C READ RECORDING RAIN GAGE HOURLY TOTALS	SHM02220
127 READ 500,IWBG,YEAR,MONTH,DATE,CN	SHM02230
C PUNCH NO NUMBERS AFTER CN ON YEAR .EQ. 98 CARD	SHM02240
IF(YEAR .GE. 98) GO TO 130	SHM02250
HRF =12*(CN-1) +1	SHM02260
HRL =12*(CN-1) + 12	SHM02270
DAY = MEDCY(MONTH) + DATE + 122	SHM02280
IF(DAY .GT. DPY) DAY= DAY-DPY	SHM02290
DO 2000 IJK = 1,12	SHM02300
IF (DAY .GT. MEDCY(IJK)) GO TO 2000	SHM02310
MONTH = IJK - 1	SHM02320
GO TO 2050	SHM02330
2000 CONTINUE	SHM02340
2050 CONTINUE	SHM02350
READ 1003,(DRHP(DAY,HOUR),HOUR=HRF,HRL)	SHM02360
DO 1291 HOUR= HRF,HRL	SHM02370
1291 DRHP(DAY,HOUR) = 0.03937*DRHP(DAY,HOUR)	SHM02380
1003 FORMAT(12F5.2)	SHM02390
IF(DPY .NE. 366 .OR. MONTH .NE. 2 .OR. DATE .NE. 29) GO TO 127	SHM02400
DO 129 HOUR=HRF,HRL	SHM02410
DRHP(366,HOUR) = DRHP(60,HOUR)	SHM02420
129 DRHP(60,HOUR) =0.0	SHM02430
GO TO 127	SHM02440
C CALCULATE PRECIPITAION WEGHTING FACTORS	SHM02450
130 IF(NSGRD .EQ. 0) GO TO 137	SHM02460
PDAY = 274	SHM02470
RDPT =0.0	SHM02480
DAY =274	SHM02490
131 EHSGD =SGRT	SHM02500
IF(SGRT.EQ. 0) EHSGD =24	SHM02510
EHSGDF =EHSGD	SHM02520
132 CONTINUE	SHM02530
DO 136 HOUR = 1,24	SHM02540
RDPT =RDPT +DRHP(DAY,HOUR)	SHM02550
IF(HOUR .NE. EHSGD) GO TO 136	SHM02560
IF(RDPT .LE. (0.0) GO TO 133	SHM02570
IF(SGRT .EQ. 0) PDAY =DAY	SHM02580
DRGPM (PDAY) =(DRSGP(DAY)*WSG +RDPT*(1.0-WSG))/RDPT	SHM02590
IF(CONOPT(1) .NE. 0) DPET(PDAY) =0.5*DPET(PDAY)	SHM02600
IF(SGRT .NE.0) PDAY =DAY	SHM02610
RDPT =0.0	SHM02620
GO TO 136	SHM02630
133 IF(DRSGP(DAY) .LE. 0.0) GO TO 135	SHM02640
DO 134 K HOUR =1,EHSGD	SHM02650
134 DRHP(DAY,KHOUR) =(WSG*DRSGP(DAY))/EHSGDF	SHM02660
135 IF(SGRT .NE. 0) PDAY=DAY	SHM02670
136 CONTINUE	SHM02680
CALL DAYNXT(DAY,DPY)	SHM02690

```

IF(DAY .EQ. 274) GO TO 137
IF(CONOPT(3) .EQ.0) GO TO 132
IF(DAY .NE. SGMD) GO TO 132
WSG =WSG2
SGRT = SGRT2
GO TO 131

```

SHM02700  
SHM02710  
SHM02720  
SHM02730  
SHM02740  
SHM02750  
SHM02760

C ADJUST RAINFALL ANOMALIES

```

137 MXTRH =2*NBTRI
IF(CONOPT(2) .EQ. 0) MXTRH = (2*NBTRI -1)/4 +1
NATRH =MXTRH/2
IF(NFTR .GE. 2) GO TO 138
IF(NATRH .LT. 12) CALL PRECHK(DRGPM,DRHP,DRSF,VWIN,SGRT,NATRH)

```

SHM02770  
SHM02780  
SHM02790  
SHM02800  
SHM02810

C SET INITIAL VALUES OF VARIABLE PARAMETERS TO BE OPTIMIZED

```

LZC =12.0
BMIR = 1.2
SUZC = 1.3
ETLF = 0.25
BUZC =1.50
SIAC =0.90
BIVF =0.90

```

SHM02820  
SHM02830  
SHM02840  
SHM02850  
SHM02860  
SHM02870  
SHM02880  
SHM02890

```

138 IF(NFTR .EQ.3) GO TO 139

```

```

SRX =0.98
NCTRI =NBTRI
CSRX =SRX
FSRX =SRX
CALL RECESS(DRSF,DPY,BFRC,IFRC,AREA,RSBD,RSBIF,NRS,RSBBF)
IF(IFRC.GE.0.3)GO TO 139
WRITE(6,6) IFRC

```

SHM02900  
SHM02910  
SHM02920  
SHM02930  
SHM02940  
SHM02950  
SHM02960  
SHM02970

```

6 FORMAT(/10X,'REJECTED IFRC =',F8.4)
IFRC =0.1
BIVF =0.0

```

SHM02980  
SHM02990  
SHM03000

```

139 IF(NFTR.GE.2)READ 103,LZC,BMIR,SUZC,ETLF,BUZC,SIAC,BIVF,LZS
IF(NFTR.EQ.3)READ 540,CSRX,FSRX,NCTRI,CHCAP,IFRC,BFRC

```

SHM03010  
SHM03020

```

540 FORMAT(2F10.5,I5,3F10.5)

```

SHM03030

```

140 BFHRC =BFRC**(1.0/24.0)
BFRL =-ALOG(BFHRC)
CALL FIXTRI(CTRI,BTRI,NBTRI,NCTRI)
TRIP =NFTR
SRX =CSRX
KHYD =1
LSHP = .FALSE.
DO 141 KIA = 1,5
KPSH(KIA) =0

```

SHM03040  
SHM03050  
SHM03060  
SHM03070  
SHM03080  
SHM03090  
SHM03100  
SHM03110  
SHM03120

```

141 HBF(KIA) =0.0

```

SHM03130

C POINT OF RETURN FOR NEW TRIP

```

142 IF(KRC .LE. 5) FTX =1.0
IF(DPY .EQ. 366) MEDWY(5) =366
PPH =1.0
IF(.NOT. LRC) PPH =3.0
IF(TRIP .NE. 1) PPH= 4.0
IPPH =PPH
FHPP =1.0/PPH
IFPRC =IFRC**(FHPP/24.0)
IFRL =-ALOG(IFPRC)

```

SHM03140  
SHM03150  
SHM03160  
SHM03170  
SHM03180  
SHM03190  
SHM03200  
SHM03210  
SHM03220  
SHM03230

VINTCR =FHPP*VINTMR	SHM03240
NCTRH =NCTRI	SHM03250
IF(CONOPT(2) .EQ. 0) NCTRH =(NCTRI -1)/4 +1	SHM03260
C DETERMINE STORM HOURS FOR ADJUSTING HYDROGRAPH SHAPE VARIABLES	SHM03270
IF(NRHP .NE. 0 .AND. TRIP .EQ.2) CALL STRHRS(RHPD,RHPH,IDY8,	SHM03280
1 IDYE,IHRB,IHRE,NHPT,MXTRH,DPY,NRHP,IBTPR)	SHM03290
HSE =0.0	SHM03300
NRTRI =0	SHM03310
PEAI =0.0	SHM03320
SPIF =0.0	SHM03330
OFUS=0.0	SHM03340
OFUSIS =0.0	SHM03350
RHFO=0.0	SHM03360
URHF =0.0	SHM03370
AMIF =0.0	SHM03380
AMNET =0.0	SHM03390
AMPET =0.0	SHM03400
AMPREC =0.0	SHM03410
AMBF =0.0	SHM03420
AMSE =0.0	SHM03430
KRS =1	SHM03440
KDRS =400	SHM03450
UZS =0.0	SHM03460
IFS =0.0	SHM03470
IF(NFTR .GE. 2) GO TO 145	SHM03480
IF(KRC .NE. 1) GO TO 143	SHM03490
BYLZS =6.00	SHM03500
LZS =BYLZS	SHM03510
GO TO 145	SHM03520
143 IF(EMLZS(11) .LT. LZS) LZS =EMLZS(11)	SHM03530
LZS =LZS*LZC/PLZC	SHM03540
IF(LLZC) LZS = LZC-(LZC-LZS)*(SATFV/RATFV )	SHM03550
IF(ABS(FTX -1.0) .LT. 0.02) GO TO 144	SHM03560
LZS= FTX*BBYLZS*LZC/BLZC	SHM03570
IF(LRC .AND.(LZC-LZS).LT. 2.0) LZC = LZS + 2.0	SHM03580
144 IF(TRIP .EQ. 3 .OR. KFFC .EQ. 1) LZS = BBYLZS	SHM03590
KFFC=0	SHM03600
145 OCT1BF = 0.05*TMRTF(1)	SHM03610
IF(DRSF(274) .LT. 0.05*TMRTF(1))OCT1BF = DRSF(274)	SHM03620
IF(DRSF(276) .LT. OCT1BF*BFRC**2) OCT1BF = DRSF(276)/BFRC**2	SHM03630
BYGWS = OCT1BF/(WCFS*BFRL*SQRT(BFRC))	SHM03640
GWS =BYGWS	SHM03650
BYLZS =LZS	SHM03660
BFNX =GWS*BFRL	SHM03670
TFCFS =BFNX*WCFS	SHM03680
WRITE(6,7) TRIP,LZC,BMIR,SUZC,ETLF,BUZC,SIAC,BIVF,BFRC,IFRC,	SHM03690
1 CSRX,FSRX,NCTRI,CHCAP	SHM03700
7 FORMAT(1H1,3X,'TRIAL RUN NUMBER',I3/5X,'PARAMETER VALUES'/10X,	SHM03710
1 5HLZC =,3X,F8.4,2X,6HBMIR =,2X,F8.4,2X,6HSUZC =,2X,F8.4,2X,	SHM03720
2 6HETLF =,2X,F8.4,2X,6HBUZC =,2X,F8.4,2X,6HSIAC =,2X,F8.4/10X,	SHM03730
3 6HBIVF =,2X,F8.4,2X,6HBFRC =,2X,F8.4,2X,6HIFRC =,2X,F8.4,2X,	SHM03740
4 6HCSRX =,2X,F8.4,2X,6HFSRX =,2X,F8.4,2X,7HNCTRI =,1X,I8/10X,	SHM03750
5 7HCHCAP =,1X,F8.0)	SHM03760
WRITE(6,8) LZS,GWS	SHM03770



8	FORMAT(/5X,'INITIAL MOISTURE STORAGEES, LZS =',F9.4,5X,'GWS =',	SHM03780
1	F9.4)	SHM03790
	AETX =24.0*EPAET/365.0	SHM03800
	AEX96 =1.2*AETX	SHM03810
	AEX90 =0.3*AETX	SHM03820
	SIAM =1.2**SIAC	SHM03830
	UZC=SUZC*AEX90+BUZC*EXP(-2.7*LZS/LZC)	SHM03840
	IF(UZC.LT.0.25)UZC=0.25	SHM03850
	MONTH =1	SHM03860
	MDAY = 273	SHM03870
	IF(TRIP.EQ. 1) GO TO 147	SHM03880
146	WRITE(6,9) (TITLE(KTA), KTA=1,20)	SHM03890
9	FORMAT(25X,20A4)	SHM03900
	WRITE(6,10) YR1,YR2	SHM03910
10	FORMAT(03X,61HOPTIMIZATION OF MODEL INPUT PARAMETERS BASED ON WATER	SHM03920
	1R YEAR 19,I2,1H-,I2)	SHM03930
	WRITE(6,11)	SHM03940
11	FORMAT(5H JUNE)	SHM03950
C	BEGIN DAY LOOP	SHM03960
147	DAY =274	SHM03970
148	CONTINUE	SHM03980
	IF(TRIP.NE. 1) GO TO 149	SHM03990
	KDRS = KDRS +1	SHM04000
	IF(RSBD(KRS) .NE. DAY) GO TO 149	SHM04010
	KDRS =1	SHM04020
	KRS =KRS +1	SHM04030
149	CONTINUE	SHM04040
	ADIF =0.0	SHM04050
	ADBF =0.0	SHM04060
	TDSF =0.0	SHM04070
	PET =DPET(DAY)	SHM04080
	IF(CONOPT(1) .NE. 2) PET= PET*EPCM(MONTH)	SHM04090
	PETU =PET	SHM04100
	TFMAX =0.0	SHM04110
	DO 190 HOUR =1,24	SHM04120
	IF(TRIP .NE. 2) GO TO 152	SHM04130
C	LOGICAL VARIABLE 'LSHP' SET TRUE DURING DURATION OF RECORDED HYDRO-	SHM04140
C	GRAPH SO SYNTHESIZED DATA MAY BE SAVED DURING CORRESPONDING PERIOD	SHM04150
	IF(KHYD .GT.NRHP) GO TO 152	SHM04160
	IF(IDYB(KHYD) .EQ. DAY .AND. IHRB(KHYD) .EQ. HOUR) LSHP = .TRUE.	SHM04170
	IF(KHYD .GE. NRHP) GO TO 150	SHM04180
	IF(IDYB(KHYD+1).EQ. DAY .AND. IHRB(KHYD+1) .EQ. HOUR) KHYD=	SHM04190
1	KHYD+1	SHM04200
150	IF(IDYE(KHYD) .NE. DAY .OR. IHRE(KHYD) .NE. HOUR) GO TO 151	SHM04210
	KHYD = KHYD + 1	SHM04220
	LSHP = .FALSE.	SHM04230
151	IF( .NOT. LSHP) GO TO 152	SHM04240
	KPSH(KHYD)= KPSH(KHYD) +1	SHM04250
	IF(KPSH(KHYD) .LT. 171) GO TO 152	SHM04260
	WRITE(6,12)	SHM04270
12	FORMAT(5X,'FLCOD HYDROGRAPH ARRAY EXCEEDED, SHORTEN NHPT OR SHIFT	SHM04280
	1TO HOURLY ROUTING')	SHM04290
	GO TO 228	SHM04300
152	CONTINUE	SHM04310

	IF((NSGRD .EQ.0) .AND. (DRHP(DAY,HOUR) .NE. 0.0) .AND.(PET .EQ.	SHM04320
1	PETU) .AND. (CONOPT(1) .NE. 0)) PET = 0.5*PET	SHM04330
153	IF(HOUR .EQ. SGRT+1) RGPM =DRGPM(DAY)	SHM04340
	IF(HOUR .EQ. 9) HSE =(FWTR*PET)/12.0	SHM04350
	IF(HOUR .EQ. 21) HSE =0.0	SHM04360
	PRH =RGPM*DRHP(DAY,HOUR)	SHM04370
	AMPREC =AMPREC + PRH	SHM04380
	ARHF =0.0	SHM04390
C 15	MIN ACCOUNTING AND ROUTING LOOP (60 MINUTES USED FOR ROUGH	SHM04400
C	ADJUSTMENT, AND 20 MINUTES FOR FINE ADJUSTMENT IN TRIP 1)	SHM04410
	DO 182 PRD= 1,IPPH	SHM04420
	IF(LSHP .AND.CONOPT(2) .EQ. 0.AND. PRD .NE. 1) KPSH(KHYD) =	SHM04430
1	KPSH(KHYD) +1	SHM04440
	PEBI =0.0	SHM04450
	PPI=0.0	SHM04460
	OFR =0.0	SHM04470
	OFRIS =0.0	SHM04480
	WI =0.0	SHM04490
	WEIFS =0.0	SHM04500
	PEP =FHPP*PRH	SHM04510
	IF(TRIP .GE.2 .AND.LNPR) CALL PREPRD(RGPM,DRHP,DAY,HOUR,DPY,PRD,	SHM04520
1	PEP,PRH)	SHM04530
	IF(PEP .GT. 0.0) GO TO 155	SHM04540
	IF(OFUS .GT. 0.0) GO TO 157	SHM04550
	IF(IFS .GT. 0.0) GO TO 167	SHM04560
	IF(TRIP .EQ. 1) GO TO 181	SHM04570
	IF(NRTRI .GT. 0) GO TO 169	SHM04580
	TRHF = 0.0	SHM04590
	IF(. NOT. LSHP) GO TO 154	SHM04600
	KHPT =KPSH(KHYD)	SHM04610
	SSR(KHYD,KHPT) =0.0	SHM04620
154	CONTINUE	SHM04630
	IF(RHFD .GT. 0.0) GO TO 178	SHM04640
	GO TO 181	SHM04650
C	RAINFALL UPPER ZONE INTERACTION	SHM04660
155	IF(PEP .GE.VINTCR) GO TO 156	SHM04670
	UZS =UZS +PEP*TPLR	SHM04680
	VINTCR = VINTCR-PEP	SHM04690
	PPI=0.0	SHM04700
	PEBI=0.0	SHM04710
	IF(OFUS .GT.0.0) GO TO 157	SHM04720
	GO TO 167	SHM04730
156	PPI =PEP-VINTCR	SHM04740
	UZS =UZS+VINTCR*TPLR	SHM04750
	VINTCR =0.0	SHM04760
	LZSR =LZS/LZC	SHM04770
	UZC =SUZC*AEX90 +BUZC*EXP(-2.7*LZSR)	SHM04780
	IF(UZC .LT. 0.25) UZC =0.25	SHM04790
	UZRXX= 2.0*ABS(UZS/UZC-1.0) +1.0	SHM04800
	FMR =(1.0/(1.0 +UZRXX))*UZRXX	SHM04810
	IF(UZS .GT. UZC) FMR =1.0-FMR	SHM04820
	PEBI=PPI*FMR	SHM04830
	UZS =UZS+PPI-PEBI	SHM04840
C	LOWER ZONE AND GROUNDWATER INFILTRATION	SHM04850

157	LZSR = LZS/LZC	SHM04860
	EID = 4.0*LZSR	SHM04870
	IF(LZSR .LE. 1.0) GO TO 158	SHM04880
	EID = 4.0+ 2.0*(LZSR-1.0)	SHM04890
	IF(LZSR .LE. 2.0) GO TO 158	SHM04900
	EID = 6.0	SHM04910
	CMIR = FHPP*SIA*BMIR/(2.0**EID)	SHM04920
158	PEBI = PEBI + OFUS	SHM04930
	CIVM = BIVF*2.0**LZSR	SHM04940
	IF(CIVM .LT. 1.0) CIVM = 1.0	SHM04950
	PEAI = PEBI*PEBI/(2.0*CMIR*CIVM)	SHM04960
	WI = PEBI*PEBI/(2.0*CMIR)	SHM04970
	IF(PEBI .GE. CMIR) WI = PEBI-0.5*CMIR	SHM04980
	IF(PEBI .GE. CMIR*CIVM) PEA I = PEBI -0.5*CMIR*CIVM	SHM04990
	WEIFS = WI-PEAI	SHM05000
	IF((PEAI-OFUS) .GT. 0.0) GO TO 159	SHM05010
	EQD = (OFUS + PEA I)/2.0	SHM05020
	GO TO 160	SHM05030
159	EQD = EQDF*((PEAI-OFUS)**0.6)	SHM05040
160	IF((OFUS+PEAI) .GT. (2.0*EQD)) EQD = 0.5* (OFUS + PEA I)	SHM05050
	IF((OFUS+PEAI) .LE. 0.001) GO TO 161	SHM05060
	OFR = FHPP*OFRF*(((OFUS + PEA I)*0.5)**1.67)*((1.0 +.6*((OFUS +	SHM05070
1	PEAI)/(2.0*EQD))**3.0)**1.67)	SHM05080
	IF(OFR .GT. (0.75*PEAI)) OFR = 0.75*PEAI	SHM05090
161	IF(FIMP .EQ. 0.0) GO TO 165	SHM05100
162	PEIS = PPI + OFUSIS	SHM05110
	IF((PEIS-OFUSIS) .GT. 0.0) GO TO 163	SHM05120
	EQDIS = (OFUSIS + PEIS)/2.0	SHM05130
	GO TO 164	SHM05140
163	EQDIS = EQDFIS*((PEIS -OFUSIS)**0.6)	SHM05150
164	IF((OFUSIS+PEIS) .GT. (2.0*EQDIS)) EQDIS = 0.5*(OFUSIS + PEIS)	SHM05160
	IF((OFUSIS + PEIS) .LE. 0.01) GO TO 165	SHM05170
	OFRIS = FHPP*OFRFIS*(((OFUSIS + PEIS)*0.5)**1.67)*((1.0 +0.6*((	SHM05180
1	OFUSIS + PEIS)/(2.0*EQDFIS))**3.0)**1.67)	SHM05190
	IF(OFRIS .GT. PEIS) OFRIS = PEIS	SHM05200
165	OFUSIS = PEIS - OFRIS	SHM05210
	OFUS = PEA I - OFR	SHM05220
	IF(OFUS .GE. 0.001) GO TO 166	SHM05230
	LZS = LZS + OFUS	SHM05240
	OFUS = 0.0	SHM05250
	OFRIS = OFRIS + OFUSIS	SHM05260
	OFUSIS = 0.0	SHM05270
166	LZRX = 1.5*ABS (LZS/LZC -1.0) +1.0	SHM05280
	FMR = (1.0/(1.0 + LZRX))**LZRX	SHM05290
	IF(LZS .LT. LZC) FMR = 1.0- FMR*(LZS/LZC)	SHM05300
	PLZS = FMR*(PEBI-WI)	SHM05310
	PGW = (1.0-FMR) *(PEBI -WI)*( 1.0 -SUBWF)*FPER	SHM05320
	GWS = GWS+PGW	SHM05330
	LZS = LZS + PLZS	SHM05340
	IFS = IFS+WEIFS*FPER	SHM05350
167	SPIF = IFRL*IFS	SHM05360
	AMIF = AMIF+SPIF	SHM05370
	ADIF = ADIF+SPIF	SHM05380
	IFS = IFS-SPIF	SHM05390

IF(IFS.GE.0.0001) GO TO 168	SHM05400
LZS=LZS+IFS	SHM05410
IFS=0.0	SHM05420
168 UHFA(1) = FPER*OFR + PPI*FWTR + FIMP*OFRIS + SPIF	SHM05430
IF(TRIP .NE. 1) GO TO 169	SHM05440
ARHF = ARHF + UHFA(1)	SHM05450
GO TO 181	SHM05460
C ROUTING	SHM05470
169 IF(CONOPT (2) .NE. 1) GO TO 170	SHM05480
URHF = URHF + 0.25*UHFA(1)	SHM05490
IF(PRD.NE. 4) GO TO 178	SHM05500
UHFA(1)=URHF	SHM05510
C SAVES SYNTHESIZED DIRECT RUNOFF AND INTER FLOW ENTERING STREAM DURING	SHM05520
C DURATION OF RECORDED HYDROGRAPH	SHM05530
170 IF( .NOT. LSHP) GO TO 171	SHM05540
KHPT = KPSH(KHYD)	SHM05550
IF(CONOPT(2) .EQ. 1) SSR(KHYD, KHPT) = 4.0*URHF*WCFS	SHM05560
IF(CONOPT(2) .EQ. 0) SSR(KHYD, KHPT) = 4.0*UHFA(1)*WCFS	SHM05570
171 CONTINUE	SHM05580
TRHF = 0.0	SHM05590
KTRI = NCTRI	SHM05600
172 URHF = UHFA(KTRI)	SHM05610
IF(URHF .LE. 0.0) GO TO 174	SHM05620
173 TRHF = TRHF + URHF*CTRI(KTRI)	SHM05630
UHFA(KTRI + 1) = URHF	SHM05640
GO TO 175	SHM05650
174 UHFA(KTRI + 1) = 0.0	SHM05660
175 KTRI = KTRI - 1	SHM05670
IF(KTRI .GE. 1) GO TO 172	SHM05680
176 IF(URHF .LE. 0.0) GO TO 177	SHM05690
NRTRI = NCTRI	SHM05700
177 NRTRI = NRTRI - 1	SHM05710
UHFA(1) = 0.0	SHM05720
URHF = 0.0	SHM05730
178 IF(TRIP .LE. 2) GO TO 179	SHM05740
IF(TFCFS .LE. 0.5*CHCAP) SRX = CSRX	SHM05750
IF((TFCFS .GT. 0.5*CHCAP) .AND. (TFCFS .LT. 2.0*CHCAP)) SRX = CSRX	SHM05760
1 + (FSRX - CSRX)*((TFCFS - 0.5*CHCAP)/(1.5*CHCAP))**3	SHM05770
IF(TFCFS .GT. 2.0*CHCAP) SRX = FSX	SHM05780
179 RHF1 = TRHF - SRX*(TRHF - RHF0)	SHM05790
RHF0 = RHF1	SHM05800
IF(RHF0.LT. RHFM) RHF0 = 0.0	SHM05810
TFCFS = (4.0*RHF1 + CBF - HSE)*WCFS	SHM05820
IF(TFCFS .LE. TFMAX) GO TO 180	SHM05830
PRDF = PRD	SHM05840
TDFP24 = HOUR	SHM05850
IF(PRD .LE. 3) TDFP24 = (TDFP24 - 1.0) + 0.15*PRDF	SHM05860
TFMAX = TFCFS	SHM05870
180 ARHF = ARHF + RHF1	SHM05880
181 IF(VINTCR .LT. FHPP*VINTMR) VINTCR = VINTCR + DPET(DAY)/(24.0/	SHM05890
1 FHPP)	SHM05900
182 CONTINUE	SHM05910
C END OF 15 MINUTE LOOP	SHM05920
C ADDING GROUNDWATER FLOW	SHM05930



183	CBF =GWS*BFRL	SHM05940
	IF(KHYD .GT. NRHP) GO TO 184	SHM05950
	IF(LSHP .AND. (HBF(KHYD) .EQ. 0.0)) HBF(KHYD) = CBF*WCFS	SHM05960
184	GWS =GWS-CBF	SHM05970
	AMBF =AMBF +CBF	SHM05980
	THGR =ARHF +CBF	SHM05990
C	EVAPORATION FROM STREAM SURFACE	SHM06000
185	IF(HSE .GT. THGR) HSE =THGR	SHM06010
	IF(CBF .GT. HSE) ADBF =ADBF +CBF -HSE	SHM06020
	AMSE =AMSE+HSE	SHM06030
	THSF(HOUR) = (THGR -HSE)*WCFS	SHM06040
	IF(TFMAX .LE. 0.0) TFMAX =THSF(HOUR)	SHM06050
	TDSF = TDSF + THSF(HOUR)	SHM06060
C	DRAINING OF UPPER ZONE STORAGE	SHM06070
	UZINFX =(UZS/UZC) -(LZS/LZC)	SHM06080
	IF(UZINFX .LE. 0.0) GO TO 186	SHM06090
	LZSR =LZS/LZC	SHM06100
	UZINLZ =0.003*BMIR*UZC*UZINFX**3.0	SHM06110
	IF(UZINLZ .GT. UZS) UZINLZ =UZS	SHM06120
	UZS =UZS -UZINLZ	SHM06130
	LZRX =1.5*ABS(LZSR -1.0)+1.0	SHM06140
	FMR =(1.0/(1.0 +LZRX))**LZRX	SHM06150
	IF(LZS .LT. LZC) FMR=1.0-FMR*LZSR	SHM06160
	PGW =(1.0-FMR)*UZINLZ*(1.0 -SUBWF)*FPER	SHM06170
	PLZS=FMR*UZINLZ	SHM06180
	LZS =LZS +PLZS	SHM06190
	GWS =GWS +PGW	SHM06200
C	4 PM ADJUSTMENTS OF VARIUS VALUES	SHM06210
186	IF(HOUR .NE. 16) GO TO 190	SHM06220
	AEX90 =0.9*(AEX90 +PET)	SHM06230
	AEX96 =0.96*(AEX96 +PET)	SHM06240
C	INFILTRATION CORRECTION	SHM06250
	SIAM =(AEX96/AETX)**SIAC	SHM06260
	IF(SIAM .LT. 0.33) SIAM =0.33	SHM06270
	IF(PET .EQ. 0.0) GO TO 190	SHM06280
C	EVAP-TRANS LOSS FROM GROUND WATER	SHM06290
	GWET =GWS*GWETF*PET*FPER	SHM06300
	GWS =GWS-GWET	SHM06310
	AMPET =AMPET +PET	SHM06320
	IF(PET .GE. UZS) GO TO 187	SHM06330
	UZS =UZS -PET	SHM06340
	AMNET =AMNET +PET	SHM06350
	GO TO 190	SHM06360
187	PET = PET-UZS	SHM06370
	AMNET =AMNET + UZS	SHM06380
	UZS =0.0	SHM06390
	LZSR = LZS/LZC	SHM06400
	IF(PET .GE. ETLF*LZSR) GO TO 188	SHM06410
	SET = PET*(1.0- PET/(2.0*ETLF*LZSR))	SHM06420
	GO TO 189	SHM06430
188	SET =0.5*ETLF*LZSR	SHM06440
189	LZS =LZS-SET	SHM06450
	AMNET =AMNET +SET	SHM06460
190	CONTINUE	SHM06470

END OF HOUR LOOP	SHM06480
DSSF(DAY) =TDSF/24.0	SHM06490
IF(TRIP.EQ. 1) GO TO 192	SHM06500
IF(TFMAX .LE. RMPF) GO TO 192	SHM06510
IF(DAY .EQ. 366) MDAY =337	SHM06520
DATE =MOD(DAY,MDAY)	SHM06530
WRITE(6,13) DATE, (THSF(HOUR),HOUR=1,12)	SHM06540
13 FORMAT(1H/,1X/,1X,I4,2X,2HAM,1X,6F8.1,3X,6F8.1)	SHM06550
WRITE(6,14) (THSF(HOUR),HOUR=13,24) , DSSF(DAY)	SHM06560
14 FORMAT(1H/,6X,2HPM,1X,6F8.1,3X,7F8.1)	SHM06570
IF(TDFP24 .LT. 12.0) GO TO 191	SHM06580
TDFP12 =TDFP24 -12.0	SHM06590
WRITE(6,15) TFMAX, TDFP12	SHM06600
15 FORMAT(1H/,10X,'MAXIMUM=',F8.1,2X,'C.F.S.',5X,'TIME',3X,F5.2,2X,	SHM06610
1 4HP.M.)	SHM06620
GO TO 192	SHM06630
191 WRITE(6,16) TFMAX,TDFP24	SHM06640
16 FORMAT(1H/,10X,8HMAXIMUM=,F8.1,2X,6HC.F.S.,5X,4HTIME,3X,F5.2,2X,	SHM06650
1 4HA.M.)	SHM06660
192 CONTINUE	SHM06670
IF(TRIP .EQ. 1 .AND. .NOT. LRC .AND. KDRS .LE. 3 .AND. IFRC .GT.	SHM06680
1 0.1) SIFRS(KDRS,KRS-1) = ADIF*VWIN	SHM06690
IF(TRIP .EQ. 1 .AND. KDRS .LE. 3) SBFRS(KDRS,KRS-1) =ADBF*VWIN	SHM06700
C MONTHLY SUMMARY STORAGE	SHM06710
IF(DAY .NE. MEDWY(MONTH)) GO TO 206	SHM06720
TMPREC(MONTH) = AMPREC	SHM06730
AMPREC =0.0	SHM06740
TMBF(MONTH) = AMBF	SHM06750
AMBF =0.0	SHM06760
TMIF(MONTH) = AMIF	SHM06770
AMIF =0.0	SHM06780
TMSE(MONTH) =AMSE	SHM06790
AMSE =0.0	SHM06800
TMPET(MONTH) = AMPET	SHM06810
AMPET =0.0	SHM06820
TMNET(MONTH) =AMNET	SHM06830
AMNET =0.0	SHM06840
EMGWS(MONTH) = GWS	SHM06850
UZC=SUZC*AEX90 +BUZC*EXP(-2.7*LZS/LZC)	SHM06860
IF(UZC .LT. 0.25) UZC =0.25	SHM06870
EMUZC(MONTH)=UZC	SHM06880
EMUZS(MONTH) =UZS	SHM06890
EMSIAM(MONTH) =SIAM	SHM06900
EMLZS(MONTH) =LZS	SHM06910
EMIFS(MONTH) =IFS	SHM06920
IF(MONTH .EQ. 5) MEDWY(5) =59	SHM06930
MDAY =MEDWY(MONTH)	SHM06940
IF(TRIP .EQ. 1) GO TO 205	SHM06950
193 GO TO (194,195,196,197,198,199,200,201,202,203,204,	SHM06960
1 205),MONTH	SHM06970
194 WRITE(6,17)	SHM06980
17 FORMAT(1H/,4HJULY)	SHM06990
GO TO 205	SHM07000
195 WRITE(6,18)	SHM07010

18	FORMAT(1H/,6HAUGUST)	SHM07020
	GO TO 205	SHM07030
196	WRITE(6,19)	SHM07040
19	FORMAT(1H/,9HSEPTEMBER)	SHM07050
	GO TO 205	SHM07060
197	WRITE(6,20)	SHM07070
20	FORMAT(1H/,7HOCTOBER)	SHM07080
	GO TO 205	SHM07090
198	WRITE(6,21)	SHM07100
21	FORMAT(1H/,8HNOVEMBER)	SHM07110
	GO TO 205	SHM07120
199	WRITE(6,22)	SHM07130
22	FORMAT(1H/,8HDECEMBER)	SHM07140
	GO TO 205	SHM07150
200	WRITE(6,23)	SHM07160
23	FORMAT(1H/,7HJANUARY)	SHM07170
	GO TO 205	SHM07180
201	WRITE(6,24)	SHM07190
24	FORMAT(1H/,8HFEBRUARY)	SHM07200
	GO TO 205	SHM07210
202	WRITE(6,25)	SHM07220
25	FORMAT(1H/,5HMARCH)	SHM07230
	GO TO 205	SHM07240
203	WRITE(6,26)	SHM07250
26	FORMAT(1H/,5HAPRIL)	SHM07260
	GO TO 205	SHM07270
204	WRITE(6,27)	SHM07280
27	FORMAT(1H/,3HMAY)	SHM07290
205	MONTH =MONTH +1	SHM07300
C	END OF DAY LOOP	SHM07310
206	CALL DAYNXT(DAY,DPY)	SHM07320
	IF(DAY .NE. 274) GO TO 148	SHM07330
	IF(TRIP .NE. 2) GO TO 208	SHM07340
C	ADJUST BASE FLOW FOR AVERAGE VALUE DURING STORM	SHM07350
	IF(NRHP .EQ. 0) GO TO 208	SHM07360
	DO 207 KHYD =1,NRHP	SHM07370
	DAY =IDYB(KHYD)	SHM07380
	IF(DSSF(DAY) .GT. HBF(KHYD)) GO TO 207	SHM07390
	HBF(KHYD) =(HBF(KHYD) +DSSF(DAY))/2.0	SHM07400
207	CONTINUE	SHM07410
208	IF(TRIP .NE. 1) WRITE(6,28) (TITLE(KTA), KTA=1,20,1)	SHM07420
28	FORMAT(1H1,25X,20A4)	SHM07430
C	ANNUAL SUMMARY	SHM07440
	APREC = 0.0	SHM07450
	ABFV=0.0	SHM07460
	ASEV=0.0	SHM07470
	ANET=0.0	SHM07480
	APET=0.0	SHM07490
	AIFV = 0.0	SHM07500
	DO 209 MONTH =1,12	SHM07510
	APREC =APREC +TMPREC(MONTH)	SHM07520
	ABFV=ABFV +TMBF(MONTH)	SHM07530
	ASEV=ASEV+ TMSE(MONTH)	SHM07540
	ANET=ANET +TMNET(MONTH)	SHM07550

APET=APET +TMPET(MONTH)	SHM07560
209 AIFV=AIFV +TMIF(MONTH)	SHM07570
WRITE(6,29)	SHM07580
29 FORMAT(1H//44X,23HSYNTHESIZED FLOWS)	SHM07590
210 IF(TRIP .EQ. 1) WRITE(6,30)	SHM07600
30 FORMAT(//5X,'SUMMARY WHILE OPTIMIZING VOLUME VARIABLES')	SHM07610
211 CALL DAYSUM(DSSF,MEDCY,DPY,SATFV,TMSTF)	SHM07620
IF(TRIP .EQ. 1) GO TO 212	SHM07630
CALL DAYOUT(DSSF,MEDWY,DPY)	SHM07640
212 WRITE(6,31) (TMSTF(KWD), KWD=1,12),SATFV	SHM07650
31 FORMAT(1X,9HSYNTHETIC,3X,12F8.1,2X,F10.1,2X,3HSFD )	SHM07660
DO 213 MONTH =1,12	SHM07670
213 TMSTFI(MONTH)= TMSTF(MONTH)/VWIN	SHM07680
SATFVI =SATFV/VWIN	SHM07690
WRITE(6,32) (TMSTFI(KWD) ,KWD=1,12),SATFVI	SHM07700
32 FORMAT(1X,5HTOTAL,8X,12F8.3,4X,F7.3,2X,6HINCHES)	SHM07710
DO 214 MONTH =1,12	SHM07720
TMOF(MONTH)=TMSTFI(MONTH)-TMIF(MONTH)-TMBF(MONTH) +	SHM07730
1 TMSE(MONTH)	SHM07740
214 IF(TMOF(MONTH) .LT. 0.0) TMOF(MONTH)=0.0	SHM07750
AOFV=SATFVI-AIFV-ABFV +ASEV	SHM07760
IF(AOFV .LT.0.0) AOFV=0.0	SHM07770
WRITE(6,33) (TMOF(KWD), KWD=1,12), AOFV	SHM07780
33 FORMAT(1X,'OVERLAND',5X,12F8.3,4X,F7.3,2X,'INCHES')	SHM07790
WRITE(6,34) (TMIF(KWD), KWD=1,12),AIFV	SHM07800
34 FORMAT(1X,9HINTERFLOW,4X,12F8.3,4X,F7.3,2X,6HINCHES)	SHM07810
WRITE(6,35) (TMBF(KWD), KWD=1,12),ABFV	SHM07820
35 FORMAT(1X,4HBASE,9X,12F8.3,4X,F7.3,2X,6HINCHES)	SHM07830
WRITE(6,36) (TMSE(KWD), KWD=1,12), ASEV	SHM07840
36 FORMAT(1X,9HSTRM EVAP,4X,12F8.3,4X,F7.3,2X,6HINCHES)	SHM07850
WRITE(6,37) (TMPREC(KWD), KWD=1,12),APREC	SHM07860
37 FORMAT( 1X,6HPRECIP,7X,12F8.2,3X,F8.2,2X,6HINCHES)	SHM07870
WRITE(6,38) (TMNET(KWD), KWD=1,12),ANET	SHM07880
38 FORMAT(1X,'EVP/TRAN-NET',2X,12F8.3,3X,F7.3,2X,'INCHES')	SHM07890
WRITE(6,39) (TMPET(KWD), KWD=1,12),APET	SHM07900
39 FORMAT(3X,10H-POTENTIAL,2X,12F8.3,3X,F7.3,2X,6HINCHES)	SHM07910
WRITE(6,40) (EMUZS(KWD), KWD=1,12)	SHM07920
40 FORMAT(1X,12HSTORAGES-UZS,2X,12F8.3,12X,6HINCHES)	SHM07930
WRITE(6,41) (EMLZS(KWD), KWD=1,12)	SHM07940
41 FORMAT(10X,3HLZS,2X,12F8.3,12X,6HINCHES)	SHM07950
WRITE(6,42) (EMIFS(KWD), KWD=1,12)	SHM07960
42 FORMAT(10X,3HIFS,2X,12F8.3,12X,6HINCHES)	SHM07970
WRITE(6,43) (EMGWS(KWD), KWD=1,12)	SHM07980
43 FORMAT(10X,3HGWS,2X,12F8.3,12X,6HINCHES)	SHM07990
WRITE(6,44) (EMUZC(KWD), KWD=1,12)	SHM08000
44 FORMAT(1X,12HINDICES-UZC ,2X,12F8.3)	SHM08010
WRITE(6,45) (EMSIAM(KWD), KWD=1,12)	SHM08020
45 FORMAT(9X,4HSIAM,2X,12F8.3)	SHM08030
AMBER =(LZS-BYLZS)*FPER+(UZS + IFS + GWS - BYGWS)*(1.0 - FWTR	SHM08040
1 ) + SATFVI +ANET*FPER+ASEV-APREC	SHM08050
WRITE(6,46) AMBER	SHM08060
46 FORMAT(1H/,7HBALANCE,5X,F10.4,2X,6HINCHES)	SHM08070
ESTABLISH WHETHER MONTH IS PREDOMINATELY BASE FLOW OR DIRECT RUNOFF	SHM08080
NOFM=0	SHM08090



MONTH1=1	SHM08100
IF(FTX .LT. 0.95) MONTH1=4	SHM08110
DO 216 MONTH=1,12	SHM08120
XMPFT(MONTH) =0.0	SHM08130
IF(MONTH .LT. MONTH1) GO TO 216	SHM08140
IF(TMSTFI(MONTH) .GT. 0.001) GO TO 215	SHM08150
XMPFT(MONTH)=1.0	SHM08160
GO TO 216	SHM08170
215 IF(TMBF(MONTH)/TMSTFI(MONTH) .GT. 0.5) XMPFT(MONTH) =1.0	SHM08180
IF(TMOF(MONTH)/TMSTFI(MONTH) .LT. 0.5) GO TO 216	SHM08190
NOFM =NOFM+1	SHM08200
XMPFT(MONTH) =2.0	SHM08210
216 CONTINUE	SHM08220
C NATURE OF TRIPS	SHM08230
C TRIP 1 OPTIMIZE VOLUME VARIABLES WHILE BYPASSING ROUTING	SHM08240
C TRIP 2 SET FLOOD HYDROGRAPH VARIABLES. CSRX,FSRX,NCTRI,CHCAP	SHM08250
C TRIP 3 FINAL RUN WITH OPTIMIZED VALUES	SHM08260
217 IF(TRIP .EQ. 1) GO TO 218	SHM08270
KRC =MNRC +1	SHM08280
IF(TRIP .EQ. 2) GO TO 226	SHM08290
GO TO 228	SHM08300
C SYSTEMATIC ADJUSTMENT OF VOLUME VARIABLES CONVERGING ON OPTIMUM VALUES	SHM08310
218 KRC=KRC +1	SHM08320
KBRC =KBRC +1	SHM08330
PLZC =LZC	SHM08340
PBMIR =BMIR	SHM08350
PSUZC =SUZC	SHM08360
PETLF =ETLF	SHM08370
PBUZC =BUZC	SHM08380
PSIAC =SIAC	SHM08390
C ADJUST FIVE VOLUME VARIABLES. LZC,SUZC,ETLF,BUZC,SIAC	SHM08400
CALL SETFVP(LZC,SUZC,ETLF,BUZC,SIAC,TMSTF,TMRTF,TMPREC,TMPET,	SHM08410
1 EMLZS,SSQM,LRC,XMPFT,FTX,NOFM,LBUZC,LETLF,LLZC,APREC,APET)	SHM08420
C ADJUST INTERFLOW VOLUME CONSTANT DURING FINE ADJUSTMENT PHASE	SHM08430
FNCTRH =NCTRH	SHM08440
IF(.NOT. LRC .AND. IFRC .GT. 0.1) CALL SETBIV(BIVF,NRS,IFRC,RSBIF,	SHM08450
1 SIFRS,FNCTRH)	SHM08460
C ADJUST INFILTRATION RATE CONSTANT BMIR	SHM08470
IF(.NOT. LBMIR) GO TO 219	SHM08480
BMIR =0.9*BMIR	SHM08490
GO TO 220	SHM08500
219 IF(ABS(FTX-1.0) .GT. 0.02 .AND. KRC.GT. 5) IFT =2	SHM08510
CALL SETBMI(BMIR,NRS,BFRC,RSBBF,SBFRS,FNCTRH,IFT)	SHM08520
220 IF((KRC .GT. 6) .AND. (LZC .GT. 29.0)) LLZC= .TRUE.	SHM08530
IF((KRC .GT. 6) .AND. (ETLF .GT. 0.59)) LETLF = .TRUE.	SHM08540
IF((KRC .GT. 6) .AND. (BUZC .GT. 3.9)) LBUZC= .TRUE.	SHM08550
IF( .NOT. LLZC) GOTO 221	SHM08560
LZC =PLZC*SATFV/RATFV	SHM08570
WRITE(6,47) LZC	SHM08580
47 FORMAT(/2X,'LZC WAS CHANGED TO',F6.2,' BASED ON ANNUAL RUNOFF VOLU	SHM08590
1ME')	SHM08600
221 IF(KRC .LT. 6 .OR. BMIR .LT. 20.0) GO TO 222	SHM08610
LBMIR = .TRUE.	SHM08620
BMIR= 20.0	SHM08630

222	IF(SSSQM .LE. SSQM .AND. ((KRC .GE. MNRC .AND. KBRC .GE. 2) .OR.	SHM08640
1	(.NOT. LRC))) GO TO 224	SHM08650
	IF(SSSQM .LE. SSQM) GO TO 142	SHM08660
	IF(KRC .GE. MNRC) KRC=KRC-1	SHM08670
	BLZC=PLZC	SHM08680
	BBMIR=PB MIR	SHM08690
	BSUZC=PSUZC	SHM08700
	BETLF= PETLF	SHM08710
	BBUZC=PBUZC	SHM08720
	BSIAC =PSIAC	SHM08730
	SSSQM=SSQM	SHM08740
	BBYLZS=BYLZS	SHM08750
	KBRC=0	SHM08760
	IF(SSQM .LT. 0.15 .AND. LRC) GO TO 223	SHM08770
	GO TO 142	SHM08780
223	LRC=.FALSE.	SHM08790
	WRITE(6,48)	SHM08800
48	FORMAT(/5X,'SHIFT TO FINE ADJUSTMENT BEGINNING AT BEST ROUGH ADJUSTMENT POINT')	SHM08810
	SSSQM= 1000.0	SHM08820
	GO TO 225	SHM08830
224	CONTINUE	SHM08840
	IF(LRC) GO TO 223	SHM08850
	IF(TRIP .GE. NLTR) GO TO 228	SHM08860
	TRIP =TRIP+1	SHM08870
225	LZC =BLZC	SHM08880
	BMIR = BBMIR	SHM08890
	SUZC = BSUZC	SHM08900
	ETLF = BETLF	SHM08910
	BUZC =BBUZC	SHM08920
	SIAC = BSIAC	SHM08930
	KFFC = 1	SHM08940
	GO TO 142	SHM08950
226	IF(NRHP .EQ. 0) GO TO 227	SHM08960
C	CORRECT SYNTHESIZED RUNOFF TO RECORDED VOLUMES	SHM08970
	CALL ADJHYD(IDYB,IDYE,IHRB,IHRE,KPSH,DPY,HBF,NRHP,DSSF,DRSF,SSR,	SHM08980
	1 LSHA)	SHM08990
C	ESTABLISH STORM AND OVERALL OPTIMUM VALUES FOR SRX AND NCTRI	SHM09000
	CALL SETHRP(CTRI,BTRI,WCFS,CONOPT(2),HBF,LSHA,SSR,NHPT,KPSH,	SHM09010
	1 IBTPR,SRX,CSRX,FSRX,CHCAP,NRHP,RHPF,NCTRI,NBTRI)	SHM09020
	IF(NCTRI .EQ. 0) GO TO 228	SHM09030
227	IF(TRIP .GE. NLTR) GO TO 228	SHM09040
	TRIP = TRIP +1	SHM09050
	GO TO 142	SHM09060
228	CONTINUE	SHM09070
	IF(NSYC .LT. NSYT) GO TO 100	SHM09080
	STOP	SHM09090
	END	SHM09100
	SUBROUTINE ADJHYD(IDYB,IDYE,IHRB,IHRE,KPSH,DPY,HBF,NRHP,DSSF,	SHM09110
	1 DRSF,SSR,LSHA)	SHM09120
C	ADJUSTS SYNTHESIZED FLOW VOLUME TO MATCH RECORDED VOLUME FOR SETTING	SHM09130
C	HYDROGRAPH ROUTTING PARAMETERS	SHM09140
	DIMENSION IDYB(5),IDYE(5),IHRB(5),KPSH(5),SSR(5,170),	SHM09150
	1 DSSF(366),DRSF(366),HBF(5),LSHA(5),IHRE(5)	SHM09160
		SHM09170

```

LOGICAL LSHA,LSHP
INTEGER DAY,DPY
LSHP = .FALSE.
KRHP = 1
DAY = 274
100 CONTINUE
IF(LSHP) GO TO 102
IF(IDYB(KRHP) .NE. DAY) GO TO 107
101 HTH= IHRB(KRHP)
HBFM= 1.0
IF(DSSF(DAY) .LT. HBF(KRHP)) HBFM= 0.0
TSHV= (24.0-HTH)*(DSSF(DAY) -HBF(KRHP))*HBFM/24.0
HBFM = 1.0
IF(DRSF(DAY) .LT.HBF(KRHP)) HBFM= 0.0
TRHV = (24.0 -HTH)*(DRSF(DAY) -HBF(KRHP))*HBFM/24.0
IF(IDYE(KRHP) .EQ. DAY) GO TO 104
LSHP = .TRUE.
GO TO 107
102 IF(DSSF(DAY) .LT. HBF(KRHP)) GO TO 103
TSHV =TSHV + DSSF(DAY) -HBF(KRHP)
103 IF(DRSF(DAY) .LT. HBF(KRHP)) GO TO 104
TRHV = TRHV + DRSF(DAY) -HBF(KRHP)
104 CONTINUE
IF(IDYE(KRHP) .NE. DAY) GO TO 107
HTH = IHRE(KRHP)
TSHV =TSHV -(24.0-HTH)*(DSSF(DAY) -HBF(KRHP))/24.0
TRHV = TRHV-(24.0 -HTH)*(DRSF(DAY) -HBF(KRHP))/24.0
LSHP =.FALSE.
SHM= TRHV/TSHV
LSHA(KRHP) = .TRUE.
IF(SHM .GT. 8.0 .OR. SHM .LT. 0.125) LSHA(KRHP) = .FALSE.
IF( .NOT. LSHA(KRHP)) GO TO 106
KPCH =KPSH(KRHP)
DO 105 KHPT = 1,KPCH
105 SSR(KRHP,KHPT) = SHM*SSR(KRHP,KHPT)
106 WRITE(6,1) KRHP,SHM
1 FORMAT(/ /10X,'VOLUME ADJUSTMENT FACTOR FOR HYDROGRAPH',I2,
1 'EQUALS',F10.4)
KRHP = KRHP + 1
IF(KRHP .GT. NRHP) RETURN
IF(IDYB(KRHP) .EQ. IDYE(KRHP-1)) GO TO 101
107 CALL DAYNXT(DAY,DPY)
IF(DAY .NE. 274) GO TO 100
RETURN
END
SUBROUTINE DAYSUM(DRSF,MEDCY,DPY,ATFV,TMTFWY)
C SUMS DAILY VALUES TO GET MONTHLY AND ANNUAL TOTALS
DIMENSION DRSF(366),EMATF(13),MEDCY(12),TMTFCY(12),TMTFWY(12)
INTEGER DAY,DPY
C SUM ANNUAL AND CUMULATIVE MONTHLY FLOWS
EMATF(1) = 0.0
ATF = 0.0
DO 101 DAY = 1,365
ATF =ATF +DRSF(DAY)

```

```

SHM09180
SHM09190
SHM09200
SHM09210
SHM09220
SHM09230
SHM09240
SHM09250
SHM09260
SHM09270
SHM09280
SHM09290
SHM09300
SHM09310
SHM09320
SHM09330
SHM09340
SHM09350
SHM09360
SHM09370
SHM09380
SHM09390
SHM09400
SHM09410
SHM09420
SHM09430
SHM09440
SHM09450
SHM09460
SHM09470
SHM09480
SHM09490
SHM09500
SHM09510
SHM09520
SHM09530
SHM09540
SHM09550
SHM09560
SHM09570
SHM09580
SHM09590
SHM09600
SHM09610
SHM09620
SHM09630
SHM09640
SHM09650
SHM09660
SHM09670
SHM09680
SHM09690
SHM09700
SHM09710

```

DO 100 KMO = 2,12	SHM09720
00 IF(DAY .EQ. MEDCY(KMO)) EMATF(KMO) = ATF	SHM09730
01 CONTINUE	SHM09740
EMATF(13) =ATF	SHM09750
ATFV =ATF +DRSF(366)	SHM09760
CALCULATE MONTHLY FLOWS	SHM09770
DO 102 KMO = 1,12	SHM09780
102 TMTFCY(KMO) =EMATF(KMO + 1) -EMATF(KMO)	SHM09790
TMTFCY(2) = TMTFCY(2) + DRSF(366)	SHM09800
CONVERT MONTHLY FLOWS TO AWATER YEAR ORDER	SHM09810
DO 103 KMO =1,9	SHM09820
103 TMTFWY(KMO+3) =TMTFCY(KMO)	SHM09830
DO 104 KMO = 10,12	SHM09840
104 TMTFWY(KMO-9) = TMTFCY(KMO)	SHM09850
RETURN	SHM09860
END	SHM09870
SUBROUTINE FIXTRI(CTRI,BTRI,NBTRI,NCTRI)	SHM09880
FIX VALUES OF THE TIME ROUTING INCREMENTS TO MATCH REQUIRED TOTAL	SHM09890
NUMBER OF VALUES	SHM09900
DIMENSION AWSBIT(99),BTRI(99),CTRI(99)	SHM09910
IF(NCTRI .GT. 99) GO TO 101	SHM09920
IF(NBTRI .NE. NCTRI) GO TO 102	SHM09930
DO 100 KRD = 1,99	SHM09940
100 CTRI(KRD) = BTRI(KRD)	SHM09950
RETURN	SHM09960
101 WRITE(6,1) NCTRI	SHM09970
1 FORMAT(5X,'NCTRI OF',I5,1X,'EXCEEDS MAXIMUM VALUE OF 99, 99 USED')	SHM09980
NCTRI = 99	SHM09990
102 DO 103 KIA = 1,99	SHM10000
103 AWSBIT(KIA) = 0.0	SHM10010
FNTRI = NCTRI	SHM10020
KB1 = 0	SHM10030
KB2 = 1	SHM10040
KB3 = 0	SHM10050
104 KB1 =KB1 + 1	SHM10060
IF(KB1 .GT. NBTRI) GO TO 107	SHM10070
KB4 = 0	SHM10080
WSBIT = BTRI(KB1)/FNTRI	SHM10090
105 KB4 = KB4 + 1	SHM10100
IF(KB4 .GT. NCTRI) GOTO 104	SHM10110
AWSBIT(KB2) =AWSBIT(KB2) + WSBIT	SHM10120
KB3 = KB3 +1	SHM10130
IF(KB3 .LT. NBTRI) GO TO 106	SHM10140
KB3 = 0	SHM10150
KB2 = KB2 + 1	SHM10160
106 GO TO 105	SHM10170
107 DO 108 KB5 = 1,99	SHM10180
108 CTRI (KB5) = AWSBIT(KB5)	SHM10190
RETURN	SHM10200
END	SHM10210
SUBROUTINE PRECHK(DRGPM,DRHP,DRSF,VWIN,SGRT,NATRH)	SHM10220
C CHECKS PRECIPITATION-STREAMFLOW ANOMALIES AND ADJUSTS PRECIPITATION	SHM10230
C WHERE NECESSARY	SHM10240
DIMENSION DRGPM(366),DRSF(366),DRHP(366,24)	SHM10250



INTEGER DAY,HCUR,SGRT	SHM10260
AHP = 0.0	SHM10270
NRHA = 24-NATRH	SHM10280
RGPM = DRGPM(90)	SHM10290
DAY=90	SHM10300
RMWR=1.25	SHM10310
DAY=DAY+1	SHM10320
IF(DAY .GT. 200 .OR. VWIN.GT.750.0) RMWR=2.00	SHM10330
RFRISE =(DRSF(DAY) -DRSF(DAY-1))/VWIN	SHM10340
DO 101 HOUR = 1,24	SHM10350
IF(HOUR .EQ. SGRT+1) RGPM =DRGPM(DAY)	SHM10360
AHP =AHP + DRHP(DAY,HOUR)*RGPM	SHM10370
IF(HOUR .NE. NRHA) GO TO 101	SHM10380
RWRAIN =AHP	SHM10390
AHP = 0.0	SHM10400
101 CONTINUE	SHM10410
IF(RFRISE .GT. RWRAIN .AND.RFRISE .GT. 0.1) GO TO 102	SHM10420
IF((RWRAIN .GT. RMWR .AND. RFRISE .LT. 0.02*RWRAIN) .OR. (RWRAIN	SHM10430
1 .GT. 3.00 .AND. RFRISE .LT. 0.05*RWRAIN)) GO TO 104	SHM10440
GO TO 108	SHM10450
102 IF(RWRAIN .GT. 0.05) GO TO 103	SHM10460
RAA = RFRISE*2.0-RWRAIN +1.0	SHM10470
DRHP(DAY,13) = RAA	SHM10480
WRITE(6,1) DAY, RAA	SHM10490
1 FORMAT(/10X,'FOR DAY',I4,1X,'RAIN ADDED OF',F7.2)	SHM10500
GO TO 108	SHM10510
103 RAM=2.0*RFRISE/RWRAIN	SHM10520
GO TO 105	SHM10530
104 RAM = 10.0 *RFRISE/RWRAIN	SHM10540
105 IF(RAM .LT. 0.0) GO TO 108	SHM10550
WRITE(6,2) DAY,RAM,RWRAIN	SHM10560
2 FORMAT(/5X,'FOR DAY',I4,1X,'RAIN ADJUSTMENT MULTIPLIER IS',F8.4,	SHM10570
1 1X,'RECORDED RAIN IS',F7.2)	SHM10580
DO 106 HOUR = 1,NRHA	SHM10590
106 DRHP(DAY,HOUR) =DRHP(DAY,HOUR)*RAM	SHM10600
IF(NATRH .EQ. 0) GO TO 108	SHM10610
NFRHA =NRHA +1	SHM10620
DO 107 HOUR =NFRHA,24	SHM10630
107 DRHP(DAY-1,HOUR) =DRHP(DAY-1,HOUR)*RAM	SHM10640
108 IF(DAY .NE. 273) GO TO 100	SHM10650
RETURN	SHM10660
END	SHM10670
SUBROUTINE RECESS(DRSF,DPY,BFRC,IFRC,AREA,RSBD,RSBIF,NRS,RSBBF)	SHM10680
ESTABLISHES RECESSION SEQUENCES	SHM10690
DIMENSION DRSF(366),LBFO(20),NDRS(20),RSBBF(20),RSBD(20),	SHM10700
1 RSBFRC(20),RSBIF(20),RSIFRC(20),RSTF(50,20)	SHM10710
LOGICAL LBFO	SHM10720
INTEGER DAY,DPY,RSBD,RSL	SHM10730
REAL IFRC	SHM10740
MRSL = 9	SHM10750
BFRC = 0.9	SHM10760
IFRC = 0.05	SHM10770
FRERS = 0.1*SQRT(AREA)	SHM10780
100 DO 101 KSD = 1,50	SHM10790

DO 101 KRS = 1,20	SHM10800
101 RSTF(KSD,KRS) = 0.0	SHM10810
KRS = 0	SHM10820
DAY = 274	SHM10830
BEGIN NEW SEQUENCE	SHM10840
102 IF(KRS .GE. 20) GO TO 109	SHM10850
KRS = KRS + 1	SHM10860
KSD = 1	SHM10870
RSF1 = DRSF(DAY)	SHM10880
CALL DAYNXT(DAY,DPY)	SHM10890
IF(DAY .EQ. 274) GO TO 107	SHM10900
RSF2 = DRSF(DAY)	SHM10910
RSBD(KRS) = DAY	SHM10920
IF(RSF2 .LT. (RSF1+FRERS).AND. (RSF2 .GT. 0.4*AREA .OR. RSF2 .GT.	SHM10930
1 10.0)) GO TO 103	SHM10940
KRS = KRS - 1	SHM10950
GO TO 102	SHM10960
103 RSTF(1,KRS) = RSF2	SHM10970
RSFM = RSF2	SHM10980
104 KSD = KSD + 1	SHM10990
CALL DAYNXT(DAY,DPY)	SHM11000
IF(DAY .EQ. 274) GO TO 107	SHM11010
RSFN = DRSF(DAY)	SHM11020
IF(RSFN .LT. (RSFM + FRERS) .AND. RSFN .GT. 0.0) GO TO 106	SHM11030
IF(KSD .GE. MRSL) GO TO 102	SHM11040
NDRS(KRS) = 0	SHM11050
DO 105 KSD = 1,MRSL	SHM11060
105 RSTF(KSD,KRS) = 0.0	SHM11070
KRS = KRS - 1	SHM11080
GO TO 102	SHM11090
106 IF(RSFN .LT. RSFM) RSFM = RSFN	SHM11100
RSTF (KSD,KRS) = RSFN	SHM11110
NDRS(KRS) = KSD	SHM11120
IF(KSD .GE. 50) GO TO 102	SHM11130
GO TO 104	SHM11140
107 IF(KSD .GE. MRSL) GO TO 109	SHM11150
NTRS = KRS - 1	SHM11160
DO 108 KSD = 1,MRSL	SHM11170
108 RSTF(KSD,KRS) = 0.0	SHM11180
GO TO 110	SHM11190
109 NTRS = KRS	SHM11200
110 CONTINUE	SHM11210
IF(NTRS .GE. 3) GO TO 111	SHM11220
IF(MRSL .LT. 7) RETURN	SHM11230
MRSL = 6	SHM11240
GO TO 100	SHM11250
C WRITE OUT ESTABLISHED ARRAY OF FLOW SEQUENCES	SHM11260
111 WRITE(6,1)	SHM11270
1 FORMAT(/5X,'FLOW SEQUENCES USED TO ESTIMATE RECESSION CONSTANTS')	SHM11280
DO 113 KRS = 1, NTRS	SHM11290
NDRSC = NDRS(KRS)	SHM11300
DO 112 KSD = 2,NDRSC	SHM11310
112 RSTF(KSD-1,KRS) = RSTF(KSD,KRS)	SHM11320
NDRS(KRS) = NDRS(KRS) - 1	SHM11330

NDRSC = NDRSC - 1	SHM11340
WRITE(6,2) KRS,(RSTF(KSD,KRS),KSD=1,NDRSC)	SHM11350
2 FORMAT(/10X,I2,5(10F8.1/12X))	SHM11360
13 CONTINUE	SHM11370
DETERMINE RECESSION CONSTANS FROM EACH SEQUENCE	SHM11380
114 DO 116 KRS = 1,NTRS	SHM11390
IF((RSTF(1,KRS) .LT. 0.4*AREA) .AND. (RSTF(2,KRS) .GT. 0.8*	SHM11400
1 (RSTF(1,KRS)))) GO TO 115	SHM11410
LBFO(KRS) = .FALSE.	SHM11420
CALL SET2RC(RSTF,KRS,NDRS(KRS),RSIFRC(KRS),RSBFRC(KRS),LBFO(KRS))	SHM11430
IF(LBFO(KRS) .OR. RSBFRC(KRS) .GT. 1.2 .OR. RSBFRC(KRS) .LT. 0.6	SHM11440
1 .OR. RSIFRC(KRS) .GT. 0.8 .OR. RSIFRC(KRS) .LT. (-0.4))GO TO 115	SHM11450
GO TO 116	SHM11460
15 LBFO(KRS) = .TRUE.	SHM11470
CALL SET1RC(RSTF,KRS,NDRS(KRS),RSBFRC(KRS))	SHM11480
16 CONTINUE	SHM11490
CALCULATE WEIGHTED AVERAGE RECESSION CONSTANTS	SHM11500
BFRC = 0.0	SHM11510
IFRC = 0.0	SHM11520
ABFSL = 0.0	SHM11530
AIFSL = 0.0	SHM11540
DO 118 KRS = 1,NTRS	SHM11550
IF(RSBFRC(KRS) .GT. 1.2 .OR. RSBFRC(KRS) .LT. 0.6) GO TO 117	SHM11560
RSL = NDRS(KRS)	SHM11570
BFRC = BFRC + RSBFRC(KRS)*RSL	SHM11580
ABFSL = ABFSL + RSL	SHM11590
IF(LBFO(KRS)) GO TO 118	SHM11600
IF(RSL .GE. 20.0) RSL = 20.0	SHM11610
IFRC = IFRC + RSIFRC(KRS)*RSL	SHM11620
AIFSL = AIFSL + RSL	SHM11630
GO TO 118	SHM11640
17 WRITE(6,3) KRS	SHM11650
3 FORMAT(10X,'SEQUENCE',I3,1X,'OMITTED IN AVERAGING')	SHM11660
18 CONTINUE	SHM11670
WRITE(6,4) ABFSL,AIFSL	SHM11680
4 FORMAT(10X,'BASE FLOW DAYS =',F5.0,2X,'INTERFLOW DAYS =',F5.0)	SHM11690
BFRC = BFRC/ABFSL	SHM11700
IFRC = IFRC/AIFSL	SHM11710
IF(BFRC .GT. 0.99) BFRC = 0.99	SHM11720
IF(BFRC .LT. 0.70) BFRC = 0.70	SHM11730
KSQ = 0	SHM11740
DO 119 KRS = 1,NTRS	SHM11750
IF(LBFO(KRS)) GO TO 119	SHM11760
CALL SETRBF(RSTF,NDRS,KRS,BFRC,IFRC,CRSBIF,CRSBBF)	SHM11770
IF(CRSBIF .GT. 95000.0 .OR. CRSBBF .LT. 0.0) GO TO 119	SHM11780
IF(CRSBIF .LT. 0.0) CRSBIF = 0.0	SHM11790
KSQ = KSQ + 1	SHM11800
RSBD (KSQ) = RSBD(KRS)	SHM11810
RSBIF(KSQ) = CRSBIF	SHM11820
RSBBF(KSQ) =CRSBBF	SHM11830
119 CONTINUE	SHM11840
NRS = KSQ	SHM11850
DO 120 KSQ = 1,NRS	SHM11860
DAY = RSBD(KSQ)	SHM11870

	CALL DAYNXT(DAY,DPY)	SHM11880
120	RSBD(KSQ) = DAY	SHM11890
	DO 121 KSQ = 1,NRS	SHM11900
	CRSBTF = RSBI(KSQ) + RSBBF(KSQ)	SHM11910
121	WRITE(6,5) KSQ,RSBD(KSQ),RSBI(KSQ),RSBBF(KSQ),CRSBTF	SHM11920
5	FORMAT(/10X,'REVISED FLOW SEQUENCE',I3,1X,'BEGINS ON DAY',I4,	SHM11930
1	1X,'AT INTERFLOW =',F7.2,1X,'CFS, BASE FLOW =',F7.2,1X,'CFS,	SHM11940
2	TOTAL =',F7.2,1X,'CFS')	SHM11950
	RETURN	SHM11960
	END	SHM11970
	SUBROUTINE SETBIV(BIVF,NRS,IFRC,RSBI,SIFRS,FNCTRH)	SHM11980
	SETS BEST VALUE OF BASIC INTERFLOW VOLUME FACTOR	SHM11990
	DIMENSION RSBI(20),SIFRS(3,20)	SHM12000
	REAL IFRC	SHM12010
	ARSTR = 0.0	SHM12020
	DO 101 KRS = 1,NRS	SHM12030
	RIF = RSBI(KRS)/IFRC	SHM12040
	DO 100 KDY = 1,3	SHM12050
	RIF = RIF*IFRC	SHM12060
	SIF = SIFRS(KDY,KRS)/IFRC** (FNCTRH/48.0)	SHM12070
	RSTR = 0.0	SHM12080
	IF(RIF .GT. 0.0) RSTR = SIF/RIF	SHM12090
	IF(RSTR .GT. 3.0 .OR. (SIF .GT. 0.0 .AND. RIF .EQ. 0.0))RSTR=3.0	SHM12100
	ARSTR = ARSTR +RSTR	SHM12110
	WRITE(6,1) KRS,KDY,SIF,RIF	SHM12120
1	FORMAT(10X,'KRS=',I3,2X,'KDY=',I2,2X,'SIF=',F7.1,5X,'RIF=',	SHM12130
	1 F7.1)	SHM12140
100	CONTINUE	SHM12150
101	CONTINUE	SHM12160
	TIRD = NRS*3	SHM12170
	PBIVF = BIVF	SHM12180
	BIVF = 0.40	SHM12190
	IF(ARSTR .GT. 0.0) BIVF = ((PBIVF-0.40)*TIRD)/ARSTR + 0.40	SHM12200
	WRITE(6,2) PBIVF,BIVF	SHM12210
2	FORMAT(5X,'BIVF CHANGED FROM',F6.2,2X,'TO',F6.2//)	SHM12220
	RETURN	SHM12230
	END	SHM12240
	SUBROUTINE SETBMI(BMIR,NRS,BFRC,RSBBF,SBFRS,FNCTRH,IFT)	SHM12250
C	SETS BEST VALUE OF BASIC MAXIMUM INFILTRATION RATE WITHIN WATERSHED	SHM12260
	DIMENSION RSBBF(20),SBFRS(3,20)	SHM12270
	ARSTR = 0.0	SHM12280
	DO 101 KRS = IFT,NRS	SHM12290
	RBF = RSBBF(KRS)/BFRC	SHM12300
	DO 100 KDY = 1,3	SHM12310
	RBF = RBF*BFRC	SHM12320
	SBF = SBFRS(KDY,KRS)/BFRC** (FNCTRH/48.0)	SHM12330
	RSTR = SBF/RBF	SHM12340
	IF(RSTR .GT. 3.0) RSTR =3.0	SHM12350
	ARSTR = ARSTR + RSTR	SHM12360
	WRITE(6,1) KRS,KDY,SBF,RBF	SHM12370
1	FORMAT(10X,'KRS=',I3,2X,'KDY=',I2,2X,'SBF=',F7.1,5X,'RBF=',	SHM12380
	1 F7.1)	SHM12390
100	CONTINUE	SHM12400
101	CONTINUE	SHM12410



	TBRD =(NRS + 1-IFT)*3	SHM12420
	ARSTR = ARSTR/TBRD	SHM12430
	ARSTR = ARSTR**1.3	SHM12440
	PBMIR =BMIR	SHM12450
	BMIR = PBMIR/ARSTR	SHM12460
	WRITE(6,2) PBMIR,BMIR	SHM12470
2	FORMAT(5X,'BMIR CHANGED FROM',F6.2,2X,'TO',F6.2//)	SHM12480
	RETURN	SHM12490
	END	SHM12500
	SUBROUTINE SETFDI(MFDP,TMSTF,TMRTF,SSQM)	SHM12510
	SETS VALUES OF FLOW DEVIATION INDICES	SHM12520
	DIMENSION MFDP(12),TMRTF(12),TMSTF(12)	SHM12530
	REAL MFDP	SHM12540
	DO 101 MONTH = 1,12	SHM12550
	IF(MONTH .LE. 2) SSQM = 0.0	SHM12560
	SMFX = TMSTF(MONTH) + 20.0	SHM12570
	RMFX = TMRTF(MONTH) + 20.0	SHM12580
	MFDP(MONTH) = SMFX/RMFX - 1.0	SHM12590
	IF(MFDP(MONTH) .GT. 8.0) MFDP(MONTH) = 8.0	SHM12600
	IF(MFDP(MONTH) .LT. 0.0) MFDP(MONTH) = 1.0 -RMFX/SMFX	SHM12610
	IF(MFDP(MONTH) .LT. (-8.0))MFDP(MONTH) = -8.0	SHM12620
100	SSQM = SSQM + MFDP(MONTH)*MFDP(MONTH)	SHM12630
101	CONTINUE	SHM12640
	WRITE(6,1) (MFDP(MONTH), MONTH=1,12), SSQM	SHM12650
1	FORMAT(/2X,'MONTHLY DEVIATIONS',/16X,12(F7.3,1X),'SSQM =',F7.3)	SHM12660
	RETURN	SHM12670
	END	SHM12680
	SUBROUTINE SETFVP(LZC,SUZC,ETLF,BUZC,SIAC,TMSTF,TMRTF,TMPREC,	SHM12690
1	TMPTET,EMLZS,SSQM,LRC,XMPFT,FTX,NOFM,LBUZC,LETLF,LLZC,APREC,APET)	SHM12700
2	SETS BEST VALUES OF FLOW VOLUME PARAMETERS	SHM12710
	DIMENSION EMLZS(12),MFDP(12),MXA(12),TMPET(12),TMPREC(12),	SHM12720
1	TMRTF(12),TMSTF(12),XMPFT(12)	SHM12730
	LOGICAL LBUZC,LETLF,LLZC,LRC	SHM12740
	REAL LZC,MFDP	SHM12750
	CALL SETFDI(MFDP,TMSTF,TMRTF,SSQM)	SHM12760
	IF((MFDP(2)+MFDP(3)) .GT. 2.0 .AND. FTX .LT. 1.05) FTX= 0.9	SHM12770
	IF((MFDP(2)+MFDP(3)) .LT. (-2.0).AND. FTX .GT. 0.95) FTX=1.1	SHM12780
C	ADJUSTMENT OF LZC BASED ON MONTHS WHERE OVER HALF OF TOTAL	SHM12790
C	SYNTHESIZED RUNOFF IS OVERLAND FLOW,MINIMUM OF TWO MONTHS	SHM12800
C	WITH GREATEST RUNOFF USEC	SHM12810
	PLZC = LZC	SHM12820
	FNOFM = NOFM	SHM12830
	IF(NOFM .GT. 2) GO TO 103	SHM12840
	M1R = 2	SHM12850
	M2R = 1	SHM12860
	IF(TMRTF(2).GT. TMRTF(1)) GO TO 100	SHM12870
	M1R = 1	SHM12880
	M2R = 2	SHM12890
100	DO 102 MONTH = 3,12	SHM12900
	IF(TMRTF(MONTH) .LT. TMRTF(M2R)) GO TO 102	SHM12910
	IF(TMRTF(MONTH) .GT. TMRTF(M1R)) GO TO 101	SHM12920
	M2R = MONTH	SHM12930
	GO TO 102	SHM12940
101	M2R = M1R	SHM12950

	PRM2 = TMPREC (MONTH)	SHM13500
112	CONTINUE	SHM13510
	FSUZC = MFDP(M1SP) + MFDP(M2SP)	SHM13520
	IF (ABS (XMPFT (12) - 1.0) .GT. 0.2) GO TO 113	SHM13530
	FSUZC = FSUZC + MFDP (12)	SHM13540
	M12 = 12	SHM13550
113	IF (ABS (XMPFT (11) - 1.0) .GT. 0.2) GO TO 114	SHM13560
	FSUZC = FSUZC + MFDP (11)	SHM13570
	M11 = 11	SHM13580
114	IF (FSUZC .GT. 1.0) FSUZC = 1.0	SHM13590
	IF (FSUZC .LT. (-1.0)) FSUZC = -1.0	SHM13600
	IF (FSUZC .GT. 0.0) SUZC = (FSUZC + 1.0) * SUZC	SHM13610
	IF (FSUZC .LE. 0.0) SUZC = SUZC / (1.0 - FSUZC)	SHM13620
	WRITE (6, 3) SUZC, M1SP, M2SP, M11, M12	SHM13630
3	FORMAT (4X, 'SUZC WAS CHANGED TO', F6.2, ' BASED ON MONTHS', 4I3)	SHM13640
	IF (SUZC .LT. 0.3 .AND. LRC) SUZC = 0.3	SHM13650
	IF (SUZC .GT. 3.0 .AND. LRC) SUZC = 3.0	SHM13660
	ADJUSTMENT OF ETLF BASED ON SUMMER MONTHS OF RAINFALL EXCEEDING TWO	SHM13670
	INCHES OR NEED TO PREVENT MOISTURE BUILDUP	SHM13680
	IF (EMLZS (12) .LT. PLZC .OR. EMLZS (11) .LT. PLZC .OR. APREC .GT.	SHM13690
	1 1.5 * APET) GO TO 115	SHM13700
	FETLF = 1.0	SHM13710
	MXA (1) = 13	SHM13720
	KWSM = 1	SHM13730
	GO TO 120	SHM13740
115	SWSMD = 0.0	SHM13750
	KWSM = 0	SHM13760
	DO 116 MONTH = 1, 12	SHM13770
	IF (MONTH .GT. MBWS .OR. MONTH .GT. 2) .AND. (MONTH .LT. MBDS	SHM13780
	1 .AND. MONTH .LT. 9)) GO TO 116	SHM13790
	IF (TMPREC (MONTH) .LT. 2.0) GO TO 116	SHM13800
	SWSMD = SWSMD + MFDP (MONTH)	SHM13810
	KWSM = KWSM + 1	SHM13820
	MXA (KWSM) = MONTH	SHM13830
116	CONTINUE	SHM13840
	IF (KWSM .GE. 1) GO TO 117	SHM13850
	MXA (1) = M1R	SHM13860
	KWSM = 1	SHM13870
	FETLF = 5.0 * MFDP (M1R)	SHM13880
	GO TO 120	SHM13890
117	WSM = KWSM	SHM13900
	IF (.NOT. LETLF .OR. KWSM .EQ. 1) GO TO 119	SHM13910
	EMFDP = 0.0	SHM13920
	DO 118 MONTH = 1, KWSM	SHM13930
	KM1 = MXA (MONTH)	SHM13940
	IF (MFDP (KM1) .LT. EMFDP) GO TO 118	SHM13950
	EMFDP = MFDP (KM1)	SHM13960
	KM2 = MONTH	SHM13970
118	CONTINUE	SHM13980
	MXA (KM2) = 0	SHM13990
	SWSMD = SWSMD - EMFDP	SHM14000
	WSM = WSM - 1.0	SHM14010
119	FETLF = 1.2 * SWSMD / WSM	SHM14020
120	IF (FETLF .GT. 1.0) FETLF = 1.0	SHM14030

	IF(FETLF .LT. (-1.0)) FETLF = -1.0	SHM14040
	IF(FETLF .GT. 0.0) ETLF = (FETLF + 1.0)*ETLF	SHM14050
	IF(FETLF .LT. 0.0) ETLF = ETLF/(1.0 - FETLF)	SHM14060
	WRITE(6,4) ETLF, (MXA(KWD), KWD = 1, KWSM)	SHM14070
4	FORMAT(4X, 'ETLF WAS CHANGED TO', F6.2, ' BASED ON MONTHS', 12I3)	SHM14080
	IF(ETLF .LT. 0.05 .AND. LRC) ETLF = 0.05	SHM14090
	IF(ETLF .GT. 0.6 .AND. LRC) ETLF = 0.6	SHM14100
	ADJUSTMENT OF BUZC BASED ON SEPTEMBER, NOVEMBER, AND DECEMBER	SHM14110
	KM1 = 12	SHM14120
	KM2 = 2	SHM14130
	KM3 = 3	SHM14140
	FBUZC = 0.4*(MFDP(12) + MFDP(2) + MFDP(3))	SHM14150
	IF( .NOT. LBUZC) GO TO 121	SHM14160
	FBUZC = 0.4*(MFDP(9) + MFDP(10) + MFDP(11))	SHM14170
	KM1 = 9	SHM14180
	KM2 = 10	SHM14190
	KM3 = 11	SHM14200
121	IF(FBUZC .GT. 1.0) FBUZC = 1.0	SHM14210
	IF(FBUZC .LT. (-1.0)) FBUZC = -1.0	SHM14220
	IF(FBUZC .GT. 0.0) BUZC = (FBUZC + 1.0)*BUZC	SHM14230
	IF(FBUZC .LE. 0.0) BUZC = BUZC/(1.0 - FBUZC)	SHM14240
	WRITE(6,5) BUZC, KM1, KM2, KM3	SHM14250
5	FORMAT(4X, 'BUZC WAS CHANGED TO', F6.2, ' BASED ON MONTHS', 3I3)	SHM14260
	IF(BUZC .LT. 0.2 .AND. LRC) BUZC = 0.2	SHM14270
	IF(BUZC .GT. 4.0 .AND. LRC) BUZC = 4.0	SHM14280
	ADJUSTMENT OF SIAC BASED ON THREE FIRST MOISTURE EXCESS AND THREE	SHM14290
	FIRST MOISTURE DEFICIENT MONTHS	SHM14300
	KM1 = MBDS	SHM14310
	KM2 = MBDS + 1	SHM14320
	KM3 = MBDS - 1	SHM14330
	KM4 = 0	SHM14340
	KM5 = 0	SHM14350
	KM6 = 0	SHM14360
	WFDX = 0.0	SHM14370
	IF(SIAC .GT. 1.0) GO TO 122	SHM14380
	WFDX = (MFDP(MBWS) + MFDP(MBWS + 1) + MFDP(MBWS + 2))/3.0	SHM14390
	IF(SIAC .GT. 0.6) WFDX = WFDX*(1.0 - SIAC)/0.4	SHM14400
	KM4 = MBWS	SHM14410
	KM5 = MBWS + 1	SHM14420
	KM6 = MBWS + 2	SHM14430
122	SFDX = (MFDP(MBDS) + MFDP(MBDS + 1) + MFDP(MBDS - 1))/3.0	SHM14440
	FSIAC = 1.5*(SFDX - WFDX)	SHM14450
	IF(FSIAC .GT. 1.0) FSIAC = 1.0	SHM14460
	IF(FSIAC .LE. (-1.0)) FSIAC = -1.0	SHM14470
	IF(SIAC .LT. 0.02) SIAC = 0.02	SHM14480
	IF(FSIAC .GT. 0.0) SIAC = (FSIAC + 1.0)*SIAC	SHM14490
	IF(FSIAC .LE. 0.0) SIAC = SIAC/(1.0 - FSIAC)	SHM14500
	WRITE(6,6) SIAC, KM4, KM5, KM6, KM3, KM1, KM2	SHM14510
6	FORMAT(4X, 'SIAC WAS CHANGED TO', F6.2, ' BASED ON MONTHS', 6I3)	SHM14520
	IF(SIAC .LT. 0.02 .AND. LRC) SIAC = 0.00	SHM14530
	IF(SIAC .GT. 4.0 .AND. LRC) SIAC = 4.0	SHM14540
	RETURN	SHM14550
	END	SHM14560
	SUBROUTINE SETHRP(CTRI, BTRI, WCFS, CONOP2, HBF, LSHA, SSR, NHPT, KPSH,	SHM14570



1	IBTPR,SRX,CSRX,FSRX,CHCAP,NRHP,RHPF,NCTRI,NBTRI)	SHM14580
	SETS BEST VALUES OF HYDROGRAPH ROUTING PARAMETERS	SHM14590
	DIMENSION BTRI(99),CTRI(99),HBF(5),HSRX(5),KPSH(5),LSHA(5),	SHM14600
1	HNTRI(5),RHPF(5),SRR(5,170),SSR(5,170),TSRX(7)	SHM14610
	LOGICAL LSHA	SHM14620
	INTEGER CONOP2,HNTRI,SNTRI	SHM14630
	REAL NHPT	SHM14640
	MHTP = 1	SHM14650
	IF(CONOP2.EQ.0) MHTP = 4	SHM14660
	MXTRI = 2*NBTRI	SHM14670
	MNTRI = NBTRI/2	SHM14680
	TSRX(1) = 0.995	SHM14690
	TSRX(2) = 0.99	SHM14700
	TSRX(3) = 0.985	SHM14710
	TSRX(4) = 0.98	SHM14720
	TSRX(5) = 0.96	SHM14730
	TSRX(6) = 0.93	SHM14740
	TSRX(7) = 0.90	SHM14750
	LNIBRS = 0	SHM14760
	DO 112 KHYD = 1,NRHP	SHM14770
	IF(.NOT. LSHA(KHYD)) GO TO 112	SHM14780
	KPCH = KPSH(KHYD)	SHM14790
	NCTRI = MNTRI	SHM14800
	CALL FIXTRI(CTRI,BTRI,NBTRI,NCTRI)	SHM14810
	KH1 = 1	SHM14820
	KH2 = 1	SHM14830
	KH3 = 1	SHM14840
	SDRSP = 80.0*CHCAP	SHM14850
	SNTRI = MXTRI	SHM14860
100	SRX = TSRX(KH1)	SHM14870
	IF(KH2.EQ.2) LNIBRS = NIBRS	SHM14880
	WRITE(6,1) NCTRI,SRX	SHM14890
1	FORMAT(/,15X,'TRIAL VALUE OF NCTRI =',I3,', SRX =',F6.3)	SHM14900
	CALL TIMERT (SSR,SRR,CTRI,NCTRI,KHYD,KPCH)	SHM14910
	CSRX = SRX	SHM14920
	FSRX = SRX	SHM14930
	CALL STORRT(SRR,CSRX,FSRX,CHCAP,CONOP2,IBTPS,SHPF,KHYD,HBF(KHYD),	SHM14940
1	NHPT,KPCH,IBTPR)	SHM14950
	LNTRI = NCTRI	SHM14960
	NIRTS = IBTPS- IBTPR*MHTP	SHM14970
	NIBRS = IABS(NIRTS)	SHM14980
	DRSP = ABS(SHPF - RHPF(KHYD))	SHM14990
	IF(NIRTS.EQ.0.OR.(KH2.EQ.2.AND. NIBRS.GE. LNIBRS).OR.	SHM15000
1	RHPF(KHYD).GT.1.2*SHPF) GO TO 103	SHM15010
	IF(NIRTS.GE.1) GO TO 109	SHM15020
101	NCTRI = NCTRI - NIRTS	SHM15030
	IF(NCTRI.LT. MNTRI) NCTRI = MNTRI	SHM15040
	IF(NCTRI.GT. MXTRI) GO TO 106	SHM15050
102	CALL FIXTRI(CTRI,BTRI,NBTRI,NCTRI)	SHM15060
	KH2 = 2	SHM15070
	GO TO 100	SHM15080
103	IF(DRSP.GT. SDRSP) GO TO 108	SHM15090
	SNTRI = LNTRI	SHM15100
	SDRSP = DRSP	SHM15110

	KH3 = 2	SHM15120
104	KH1 = KH1 + 1	SHM15130
	IF(KH1 .EQ. 8) GO TO 105	SHM15140
	KH2 = 1	SHM15150
	GO TO 100	SHM15160
105	HNTRI(KHYD) = LNTRI	SHM15170
	HSRX(KHYD) = SRX	SHM15180
	GO TO 111	SHM15190
106	IF(KH1 .GE. 2 .AND. KH3 .EQ. 2 .AND. DRSP .GE. SDRSP) GO TO 108	SHM15200
	NCTRI = MXTRI	SHM15210
	CALL FIXTRI(CTRI,BTRI,NBTRI,NCTRI)	SHM15220
	IF(KH2 .EQ. 2 .AND. KH1 .EQ. 1 .AND. SHPF .GT. RHPF(KHYD)) GO	SHM15230
	1 TO 107	SHM15240
	IF( KH2 .EQ. 2 .OR. KH1 .GE. 2) GO TO 109	SHM15250
	GO TO 102	SHM15260
107	HNTRI(KHYD) = MXTRI	SHM15270
	HSRX(KHYD) = 0.995	SHM15280
	GO TO 111	SHM15290
108	HSRX(KHYD) = TSRX(KH1-1)	SHM15300
	HNTRI(KHYD) = SNTRI	SHM15310
	GO TO 111	SHM15320
109	IF(NCTRI .GT. MNTRI .AND. NCTRI .LT. MXTRI) GO TO 101	SHM15330
	IF(DRSP .GT. SDRSP) GO TO 110	SHM15340
	SDRSP = DRSP	SHM15350
	SNTRI = LNTRI	SHM15360
	GO TO 104	SHM15370
110	HNTRI(KHYD) = NCTRI	SHM15380
	HSRX(KHYD) = 0.995	SHM15390
	IF(KH1 .GE. 2) HSRX(KHYD) = TSRX(KH1 - 1)	SHM15400
111	IF(HSRX(KHYD) .LT. 0.91 .AND. SHPF .LT. 0.5*RHPF(KHYD)) LSHA(KHYD)	SHM15410
	1 = .FALSE.	SHM15420
	IF(.NOT. LSHA(KHYD)) GO TO 112	SHM15430
	WRITE(6,2) KHYD,HNTRI(KHYD),HSRX(KHYD)	SHM15440
2	FORMAT(10X,'FOR STORM ',I2,' NCTRI =',I3,' SRX =',F6.3)	SHM15450
112	CONTINUE	SHM15460
	KPA = 1	SHM15470
113	ARHPF = 0.0	SHM15480
	APPKP = 0.0	SHM15490
	DO 114 KHYD = 1,NRHP	SHM15500
	IF( .NOT. LSHA(KHYD)) GO TO 114	SHM15510
	CHPV = HNTRI(KHYD)	SHM15520
	IF(KPA .EQ. 2) CHPV = HSRX(KHYD)	SHM15530
	APPKP = APPKP + CHPV*RHPF(KHYD)	SHM15540
	ARHPF = ARHPF + RHPF(KHYD)	SHM15550
114	CONTINUE	SHM15560
	WAPV = APPKP/ARHPF	SHM15570
	IF(KPA .EQ. 2) GO TO 115	SHM15580
	NCTRI = WAPV + 0.5	SHM15590
	WRITE(6,3) NCTRI	SHM15600
3	FORMAT(//10X,'OPTIMUM NCTRI =',I3)	SHM15610
	IF(NCTRI .EQ. 0) RETURN	SHM15620
	CALL FIXTRI(CTRI,BTRI,NBTRI,NCTRI)	SHM15630
	WRITE(6,4) (CTRI(KTRI), KTRI = 1,NCTRI)	SHM15640
4	FORMAT(18X,'CTRI ARE'/9(16X,11F8.4/))	SHM15650

	WRITE(6,5)	SHM15660
5	FORMAT(18X,'WARNING- THE USER MAY HAVE TO ADJUST THESE VALUES TO	SHM15670
	1 MAKE THEM ADD TO ONE TO COMPENSATE FOR ROUNDING.')	SHM15680
	KPA = 2	SHM15690
	GO TO 113	SHM15700
115	SRX = WAPV	SHM15710
	CSRX = SRX	SHM15720
	FSRX = SRX	SHM15730
	CALL SETSRP(CONOP2,NRHP,LSHA,RHPF,HSRX,CHCAP,SSR,SRR,CTRI,CSRX,	SHM15740
1	FSRX,KHYD,IBTPS,SHPF,NCTRI,HBF,NHPT,KPSH,IBTPR)	SHM15750
	SRX = CSRX	SHM15760
	RETURN	SHM15770
	END	SHM15780
	SUBROUTINE SETRBF(RSTF,NDRS,KRS,BFRC,IFRC,CRSBIF,CRSBBF)	SHM15790
	SETS VALUES OF INTERFLOW AND BASE FLOW AT RECESSION BEGINNING	SHM15800
	DIMENSION RSTF(50,20),NDRS(20)	SHM15810
	REAL*8 RA1,RA2,RA3,RA4,RA5,RA6	SHM15820
	REAL IFRC	SHM15830
	RA1 = 0.0	SHM15840
	RA2 = 0.0	SHM15850
	RA3 = 0.0	SHM15860
	RA4 = 0.0	SHM15870
	RA5 = 0.0	SHM15880
	MNDRS = 12	SHM15890
	IF(NDRS(KRS) .LT. 12) MNDRS = NDRS(KRS)	SHM15900
	IF(IFRC .GE. 0.3) GO TO 101	SHM15910
	CRSBIF = 0.0	SHM15920
	DO 100 KSD = 1,MNDRS	SHM15930
	RA1 = RA1 + BFRC**(2*KSD)	SHM15940
100	RA4 = RA4 + RSTF(KSD,KRS)*(BFRC**KSD)	SHM15950
	CRSOBF = RA4/RA1	SHM15960
	CRSBBF = CRSOBF*BFRC	SHM15970
	RETURN	SHM15980
101	CRSBIF = 100000.0	SHM15990
	DO 102 KSD = 1,MNDRS	SHM16000
	RA1 = RA1 + BFRC**(2*KSD)	SHM16010
	RA2 = RA2 + IFRC**(2*KSD)	SHM16020
	RA3 = RA3 + (BFRC*IFRC)**KSD	SHM16030
	RA4 = RA4 + RSTF(KSD,KRS)*(BFRC**KSD)	SHM16040
	RA5 = RA5 + RSTF(KSD,KRS)*(IFRC**KSD)	SHM16050
102	CONTINUE	SHM16060
	RA6 = RA1*RA2 -RA3**2	SHM16070
	IF(RA6 .EQ. 0.0) RETURN	SHM16080
	CRSOIF = -(RA3/RA6)*RA4 +(RA1/RA6)*RA5	SHM16090
	CRSBIF = CRSOIF*IFRC	SHM16100
	CRSOBF = (RA2/RA6)*RA4 -(RA3/RA6)*RA5	SHM16110
	CRSBBF = CRSOBF*BFRC	SHM16120
	RETURN	SHM16130
	END	SHM16140
	SUBROUTINE SETSRP(CONOP2,NRHP,LSHA,RHPF,HSRX,CHCAP,SSR,SRR,CTRI,	SHM16150
1	CSRX,FSRX,KHYD,IBTPS,SHPF,NCTRI,HBF,NHPT,KPSH,IBTPR)	SHM16160
	SETS BEST VALUES OF STORAGE ROUTING PARAMETERS	SHM16170
	DIMENSION CTRI(99),HBF(5),HSRX(5),KPSH(5),LSHA(5),RHPF(5),	SHM16180
1	SRR(5,170),SSR(5,170)	SHM16190

```

LOGICAL LSHA
INTEGER CONOP2
REAL NHPT
KLCCA = 1
SRX = CSRX
EPS = 0.000001
NORHP = NRHP
DO 100 KHYD = 1, NORHP
  IF( .NOT. LSHA(KHYD)) NRHP = NRHP-1
100 CONTINUE
  IF(NRHP .LE. 2) GO TO 103
  FIND REGRESSION LINE FOR DETERMINING CSRX, WHEN NRHP EXCEEDS 3
  RA1 = 0.0
  RA2 = 0.0
  RA3 = 0.0
  RA4 = 0.0
  FNRHP = NRHP
  DO 101 KHYD = 1, NORHP
    IF(.NOT. LSHA(KHYD)) GO TO 101
    RA1 = RA1 + RHPF(KHYD)
    RA2 = RA2 + HSRX(KHYD)
    RA3 = RA3 + RHPF(KHYD)*HSRX(KHYD)
    RA4 = RA4 + RHPF(KHYD)**2
101 CONTINUE
    AVRHPF = RA1/FNRHP
    ASRX = RA2/FNRHP
    RSLP = (RA3 - RA1*ASRX)/(RA4 - RA1**2/FNRHP)
    IF(RSLP .LE. EPS) GO TO 106
    RINT = ASRX - RSLP*AVRHPF
102 CSRX = RINT + RSLP*(0.5*CHCAP)
    IF(CSRX .GE. 0.99) RETURN
    IF(CSRX .LE. 0.8) CSRX = 0.8
    GO TO 107
103 K1AH = 0
    DO 104 KHYD = 1, NORHP
      IF(.NOT. LSHA(KHYD)) GO TO 104
      IF(K1AH .EQ. 0) K1AH = KHYD
      IF(K1AH .GT. 0) K2AH = KHYD
104 CONTINUE
      IF(NRHP .EQ. 1) GO TO 105
C FIT THE STRAGHT LINE WHEN NRHP = 2
      RSLP = (HSRX(K1AH) - HSRX(K2AH))/(RHPF(K1AH) - RHPF(K2AH))
      IF(RSLP .LE. EPS) GO TO 106
      RINT = HSRX(K1AH) - RSLP*RHPF(K1AH)
      GO TO 102
105 CONTINUE
      CSRX = HSRX(K1AH)
      FSRX = CSRX
      GO TO 115
106 CONTINUE
      CSRX = SRX
      FSRX = CSRX
      WRITE(6,1)
1  FORMAT(/10X, 'REGRESSION LINE HAS NEGATIVE SLOPE')

```

```

SHM16200
SHM16210
SHM16220
SHM16230
SHM16240
SHM16250
SHM16260
SHM16270
SHM16280
SHM16290
SHM16300
SHM16310
SHM16320
SHM16330
SHM16340
SHM16350
SHM16360
SHM16370
SHM16380
SHM16390
SHM16400
SHM16410
SHM16420
SHM16430
SHM16440
SHM16450
SHM16460
SHM16470
SHM16480
SHM16490
SHM16500
SHM16510
SHM16520
SHM16530
SHM16540
SHM16550
SHM16560
SHM16570
SHM16580
SHM16590
SHM16600
SHM16610
SHM16620
SHM16630
SHM16640
SHM16650
SHM16660
SHM16670
SHM16680
SHM16690
SHM16700
SHM16710
SHM16720
SHM16730

```



	GO TO 115	SHM16740
107	CONTINUE	SHM16750
	BISRX = 0.2*(0.99 - CSRX)	SHM16760
	SISRX = 0.04*(0.99-CSRX)	SHM16770
	TFSRX = CSRX	SHM16780
	KISRX = 0	SHM16790
108	KISRX = KISRX + 1	SHM16800
	FSRX = TFSRX	SHM16810
	WRITE(6,2) KISRX,CSRX,FSRX,CHCAP	SHM16820
2	FORMAT(/15X,'TRIAL',I3,',', CSRX =',F8.5,', FSRX =',F8.5,	SHM16830
1	1 ', CHCAP =',F10.0)	SHM16840
	SQPKD = 0.0	SHM16850
	ADRSP = 0.0	SHM16860
	DO 109 KHYD = 1,NORHP	SHM16870
	IF(.NOT. LSHA(KHYD)) GO TO 109	SHM16880
	KPCH = KPSH(KHYD)	SHM16890
	CALL TIMERT(SSR,SRR,CTRI,NCTRI,KHYD,KPCH)	SHM16900
	CALL STORRT(SRR,CSRX,FSRX,CHCAP,CONDP2,IBTPS,SHPF,KHYD,HBF(KHYD),	SHM16910
1	1 NHPT,KPCH,IBTPR)	SHM16920
	DRSP = SHPF - RHPF(KHYD)	SHM16930
	SQPKD = SQPKD + DRSP**2	SHM16940
	ADRSP = ADRSP +DRSP	SHM16950
109	CONTINUE	SHM16960
	WRITE(6,3) SQPKD	SHM16970
3	FORMAT(/25X,'SQPKD =',F14.0)	SHM16980
	IF(KISRX .NE. 1) GO TO 110	SHM16990
	TFSRX = CSRX + BISRX	SHM17000
	SSQPKD = SQPKD	SHM17010
	BFSRX = FSRX	SHM17020
	GO TO 108	SHM17030
110	IF(SQPKD .GT. SSQPKD) GO TO 113	SHM17040
	IF(KISRX .EQ. 6 .AND. ADRSP .GT. 0.0) GO TO 111	SHM17050
	SSQPKD = SQPKD	SHM17060
	BFSRX = FSRX	SHM17070
	IF(KISRX .GE. 11) GO TO 114	SHM17080
	IF(KISRX .LE. 5) TFSRX = TFSRX +BISRX	SHM17090
	IF(KISRX .GE. 6) TFSRX =TFSRX -SISRX	SHM17100
	GO TO 108	SHM17110
111	KLCCA = KLCCA + 1	SHM17120
	IF(KLCCA .GE. 5) GO TO 112	SHM17130
	CHCAP = 0.8*CHCAP	SHM17140
	CSRX = RINT + RSLP*(0.5*CHCAP)	SHM17150
	GO TO 107	SHM17160
112	CSRX = 0.990	SHM17170
	FSRX = 0.990	SHM17180
	GO TO 115	SHM17190
113	IF(KISRX .GT. 6) GO TO 114	SHM17200
	KISRX = 5	SHM17210
	SSQPKD = SQPKD	SHM17220
	BFSRX = FSRX	SHM17230
	TFSRX = TFSRX -SISRX	SHM17240
	GO TO 108	SHM17250
114	FSRX = BFSRX	SHM17260
	WRITE(6,4) CSRX,FSRX,SSQPKD	SHM17270



4	FORMAT(//10X,'CSRX =',F7.4,10X,'FSRX =',F7.4,10X,'SQPKD =',F15.2)	SHM17280
	RETURN	SHM17290
115	WRITE(6,5) CSRX,FSRX	SHM17300
5	FORMAT(//10X,'CSRX =',F7.4,10X,'FSRX =',F7.4)	SHM17310
	RETURN	SHM17320
	END	SHM17330
	SUBROUTINE SET1RC(RSTF,KRS,NDRSC,BFRC)	SHM17340
	SETS BEST VALUE FOR ONE RECESSION CONSTANT	SHM17350
	DIMENSION RSTF(50,20)	SHM17360
	RA1 = 0.0	SHM17370
	RA2 = 0.0	SHM17380
	NDRSC1 = NDRSC - 1	SHM17390
	DO 100 KSD = 1,NDRSC1	SHM17400
	RA1 = RA1 + RSTF(KSD,KRS)**2	SHM17410
100	RA2 = RA2 + RSTF(KSD,KRS)*RSTF(KSD+1,KRS)	SHM17420
	BFRC = RA2/RA1	SHM17430
	WRITE(6,1) KRS,BFRC	SHM17440
1	FORMAT(15X,'KRS =',I3,5X,'BFRC =',F8.4)	SHM17450
	RETURN	SHM17460
	END	SHM17470
	SUBROUTINE SET2RC(RSTF,KRS,NDRSC,IFRC,BFRC,LBFO)	SHM17480
	SETS BEST VALUES FOR TWO RECESSION CONSTANTS	SHM17490
	DIMENSION RSTF(50,20)	SHM17500
	LOGICAL LBFO	SHM17510
	REAL IFRC	SHM17520
	REAL*8 RA1,RA2,RA3,RA4,RA5,CRSTF(50),RA6,DBFRC,DIFRC,RA,RB,RD	SHM17530
	DO 100 KSD = 1,NDRSC	SHM17540
100	CRSTF(KSD) = RSTF(KSD,KRS)	SHM17550
	NDRSC2 = NDRSC - 2	SHM17560
	RA1 = 0.0	SHM17570
	RA2 = 0.0	SHM17580
	RA3 = 0.0	SHM17590
	DO 101 KSD = 1,NDRSC2	SHM17600
	RA1 = RA1 + CRSTF(KSD)**2	SHM17610
	RA2 = RA2 + CRSTF(KSD)*CRSTF(KSD+1)	SHM17620
101	RA3 = RA3 + CRSTF(KSD)*CRSTF(KSD+2)	SHM17630
	RA4 = RA1 + CRSTF(NDRSC-1)**2 - CRSTF(1)**2	SHM17640
	RA5 = RA2 + CRSTF(NDRSC-1)*CRSTF(NDRSC) - CRSTF(1)*CRSTF(2)	SHM17650
	RA6 = RA4*RA1 - RA2**2	SHM17660
	IF(RA6 .EQ. 0.0) GO TO 102	SHM17670
	RA5 = RA5/RA6	SHM17680
	RA3 = RA3/RA6	SHM17690
	RA = RA1*RA5 - RA2*RA3	SHM17700
	RB = RA4*RA3 - RA2*RA5	SHM17710
	RD = RA**2 + 4.0*RB	SHM17720
	IF(RD .LT. 0.0) GO TO 102	SHM17730
	DBFRC = (RA + RD **0.5)/2.0	SHM17740
	DIFRC = RA - DBFRC	SHM17750
	BFRC = DBFRC	SHM17760
	IFRC = DIFRC	SHM17770
	WRITE(6,1) KRS,BFRC,IFRC	SHM17780
1	FORMAT(15X,'KRS =',I3,5X,'BFRC =',F8.4,5X,'IFRC =',F8.4)	SHM17790
	GO TO 103	SHM17800
102	LBFO = .TRUE.	SHM17810

	WRITE(6,2) KRS	SHM17820
2	FORMAT(/15X,'IMAGINARY VALUES ENCOUNTERED IN SET2RC, SEQUENCE =',	SHM17830
1	I3)	SHM17840
103	RETURN	SHM17850
	END	SHM17860
	SUBROUTINE STCRRT(SRR,CSRX,FSRX,CHCAP,CONOP2,IBTPS,SHPF,KHYD,	SHM17870
1	CHBF,NHPT,KPCH,IBTPR)	SHM17880
	PERFORMS CHANNEL STORAGE ROUTING	SHM17890
	DIMENSION ASRR(5,21),SRR(5,170)	SHM17900
	INTEGER CONOP2,PRD	SHM17910
	REAL NHPT	SHM17920
	WRITE(6,1) CHBF	SHM17930
1	FORMAT(/25X,'BASE FLOW =',F7.1,' CFS')	SHM17940
	TFCFS = CHBF	SHM17950
	INHPT = NHPT	SHM17960
	MHTP = 1	SHM17970
	IF(CONOP2 .EQ. 0) MHTP = 4	SHM17980
	INHPT = MHTP*INHPT	SHM17990
	SHPF = 0.0	SHM18000
	RHFO = 0.9*SRR(KHYD,1)	SHM18010
	KAFH = 0	SHM18020
	DO 102 KHPT = 1,KPCH	SHM18030
	PRD = 0	SHM18040
100	PRD = PRD + 1	SHM18050
	TRHF = SRR(KHYD,KHPT)	SHM18060
	IF(TFCFS .LE. 0.5*CHCAP) SRX = CSRX	SHM18070
	IF((TFCFS .GT. 0.5*CHCAP) .AND. (TFCFS .LT. 2.0*CHCAP)) SRX =	SHM18080
1	CSRX + (FSRX - CSRX)*((TFCFS - 0.5*CHCAP)/(1.5*CHCAP))**3	SHM18090
	IF(TFCFS .GE. 2.0*CHCAP) SRX = FSX	SHM18100
	RHF1 = TRHF - SRX*(TRHF - RHFO)	SHM18110
	RHFO = RHF1	SHM18120
	TFCFS = RHF1 + CHBF	SHM18130
	IF(TFCFS .LT. SHPF) GO TO 101	SHM18140
	SHPF = TFCFS	SHM18150
	IBTPS = KHPT	SHM18160
101	IF(PRD .LE. 3 .AND. CONOP2 .EQ. 1) GO TO 100	SHM18170
	KAHP = KHPT - IBTPR*MHTP + 5*INHPT	SHM18180
	IF(KAHP .LT. 0) GO TO 102	SHM18190
	IF(MOD(KAHP,INHPT) .NE. 0) GO TO 102	SHM18200
	KAFH = KAFH + 1	SHM18210
	ASRR(KHYD,KAFH) = TFCFS	SHM18220
102	CONTINUE	SHM18230
	IF(KAFH .EQ. 21) GO TO 104	SHM18240
	KAFH = KAFH + 1	SHM18250
	DO 103 KIA = KAFH,21	SHM18260
103	ASRR(KHYD,KIA) = 0.0	SHM18270
104	WRITE(6,2) KHYD,NHPT,(ASRR(KHYD,KWD), KWD = 1,21)	SHM18280
2	FORMAT(/25X,'SYNTHESIZED HYDROGRAPH',I3,' INTERVAL =',F5.2,	SHM18290
1	'HOURS'/3(22X,7F10.1/))	SHM18300
	WRITE(6,3) SHPF	SHM18310
3	FORMAT(25X,'FLOOD PEAK =',F10.1,' CFS')	SHM18320
	RETURN	SHM18330
	END	SHM18340
	SUBROUTINE STRHRS(RHPD,RHPH,IDYB,IDYE,IHRB,IHRE,NHPT,MXTRH,DPY,	SHM18350

1	NRHP,IBTPR)	SHM18360
	SETS BEGINNING AND END TIMES OF RUNOFF ENTERING RECORDED HYDROGRAPHS	SHM18370
	DIMENSION RHP(5),RHPH(5),IDYB(5),IDYE(5),IHRB(5),IHRE(5)	SHM18380
	INTEGER DAY,DPY,RHPD,RHPH	SHM18390
	REAL NHPT	SHM18400
	ESTIMATE HOURS EACH WAY FROM PEAK	SHM18410
	INHPT = NHPT	SHM18420
	IBTPR = 5*INHPT + MXTRH	SHM18430
	IPTE = 15*INHPT	SHM18440
	DETERMINE TIME OF BEGINNING AND ENDING FOR EACH STORM	SHM18450
	DO 106 KRHP = 1, NRHP	SHM18460
	KHBCK = IBTPR - RHPH(KRHP)	SHM18470
	IF(KHBCK .LT. 0) GO TO 101	SHM18480
	KDBCK = KHBCK/24 + 1	SHM18490
	IHRB(KRHP) = 24*KDBCK-KHBCK	SHM18500
	DAY = RHPD(KRHP)	SHM18510
100	DAY = DAY -1	SHM18520
	IF(DAY.EQ. 59 .AND. DPY .EQ. 366) DAY = 366	SHM18530
	IF(DAY .EQ. 365) DAY = 59	SHM18540
	IF(DAY .EQ. 0) DAY = 365	SHM18550
	KDBCK = KDBCK - 1	SHM18560
	IF(KDBCK .GT. 0) GO TO 100	SHM18570
	IDYB(KRHP) = DAY	SHM18580
	GO TO 102	SHM18590
101	IDYB(KRHP) = RHPD(KRHP)	SHM18600
	IHRB(KRHP) = RHPH(KRHP) - IBTPR	SHM18610
102	KHFOR = IPTE + RHPH(KRHP)	SHM18620
	IF(KHFOR .LE. 24) GO TO 105	SHM18630
	KDFOR = KHFOR/24	SHM18640
	IHRE(KRHP) = KHFOR - 24*KDFOR	SHM18650
	IF(IHRE(KRHP) .NE. 0) GO TO 103	SHM18660
	KDFOR = KDFOR - 1	SHM18670
103	DAY = RHPD(KRHP)	SHM18680
104	CALL DAYNXT(DAY,DPY)	SHM18690
	KDFOR = KDFOR - 1	SHM18700
	IF(KDFOR .GT. 0) GO TO 104	SHM18710
	IDYE(KRHP) = DAY	SHM18720
	GO TO 106	SHM18730
105	IDYE(KRHP) = RHPD(KRHP)	SHM18740
	IHRE(KRHP) = RHPH(KRHP) + IPTE	SHM18750
106	CONTINUE	SHM18760
C	ELIMINATE HYDROGRAPH OVERLAPPING	SHM18770
	NRHP1 = NRHP - 1	SHM18780
	IF(NRHP1 .EQ. 0) GO TO 109	SHM18790
	DO 108 KRHP = 1, NRHP1	SHM18800
	IF(((IDYE(KRHP) .GT. IDYB(KRHP+1) .AND. (.NOT. ((IDYE(KRHP) .GE. 274 .AND. IDYB(KRHP+1) .LE. 273) .OR. IDYE(KRHP) .EQ. 366))) .OR. ((IDYE(KRHP) .EQ. IDYB(KRHP+1) .AND. IHRE(KRHP) .GT. IHRB(KRHP+1) ))) GO TO 107	SHM18810
1	274 .AND. IDYB(KRHP+1) .LE. 273) .OR. IDYE(KRHP) .EQ. 366))) .OR.	SHM18820
2	((IDYE(KRHP) .EQ. IDYB(KRHP+1) .AND. IHRE(KRHP) .GT. IHRB(KRHP+1)	SHM18830
3	))) GO TO 107	SHM18840
	GO TO 108	SHM18850
107	IDYE(KRHP) = IDYB(KRHP+1)	SHM18860
	IHRE(KRHP) = IHRB(KRHP+1)	SHM18870
108	CONTINUE	SHM18880
109	IF(IDYB(1) .LE. 273 .AND. RHPD(1) .GE. 274 .AND. RHPD(1) .NE. 366)	SHM18890

1	GO TO 110	SHM18900
	GO TO 111	SHM18910
110	IDYB(1) = 274	SHM18920
	IHRB(1) = 1	SHM18930
111	IF(IDYE(NRHP) .GE. 274 .AND. RHPD(NRHP) .LE. 273 .AND. IDYE(NRHP)	SHM18940
1	1 .NE. 366) GO TO 112	SHM18950
	GO TO 113	SHM18960
112	IDYE(NRHP) = 273	SHM18970
	IHRE(NRHP) = 24	SHM18980
113	CONTINUE	SHM18990
	DO 114 KRHP = 1,NRHP	SHM19000
	WRITE(6,1) KRHP,IDYB(KRHP),IHRB(KRHP),IDYE(KRHP),IHRE(KRHP)	SHM19010
1	FORMAT(5X,'RUNOFF CONTRIBUTING TO RECORDED HYDROGRAPH',I2/10X,	SHM19020
1	1 'BEGINS ON DAY',I4,' AT HOUR',I3/10X,'AND ENDS ON DAY',I4,	SHM19030
2	2 ' AT HOUR',I3)	SHM19040
114	CONTINUE	SHM19050
	RETURN	SHM19060
	END	SHM19070
	SUBROUTINE TIMERT(SSR,SRR,CTRI,NCTRI,KRHP,KPCH)	SHM19080
	PERFORMS CHANNEL TIME ROUTING	SHM19090
	DIMENSION SSR(5,170),SRR(5,170),CTRI(99)	SHM19100
	DO 100 KHPT = 1,KPCH	SHM19110
100	SRR(KRHP,KHPT) = 0.0	SHM19120
	KTRI = 1	SHM19130
101	CONTINUE	SHM19140
	DO 102 KHPT = KTRI,KPCH	SHM19150
	NRTRI = KHPT -KTRI + 1	SHM19160
102	SRR(KRHP,KHPT) = CTRI(KTRI)*SSR(KRHP,NRTRI) + SRR(KRHP,KHPT)	SHM19170
	KTRI = KTRI + 1	SHM19180
	IF(KTRI .LE. NCTRI) GO TO 101	SHM19190
	RETURN	SHM19200
	END	SHM19210
	SUBROUTINE DAYNXT(DAY,DPY)	SHM19220
C	DETERMINES NUMBER OF NEXT DAY OF THE YEAR	SHM19230
	INTEGER DAY,DPY	SHM19240
	DAY = DAY+1	SHM19250
	IF(DAY .EQ. 366) DAY = 1	SHM19260
	IF(DAY .EQ. 60 .AND. DPY .EQ. 366) DAY = 366	SHM19270
	IF(DAY .EQ.367) DAY=60	SHM19280
	RETURN	SHM19290
	END	SHM19300
	SUBROUTINE EVPDAY(DPET,EMAET)	SHM19310
C	DETERMINES DATED PAN EVAPORATION TOTALS	SHM19320
	DIMENSION DPET(366)	SHM19330
	RETURN	SHM19340
	END	SHM19350
	SUBROUTINE DAYOUT(VDCY,MEDWY,DPY)	SHM19360
C	PRINTS TABLE OF DAILY VALUES	SHM19370
	DIMENSION MEDWY(12),VDCY(366),VDM(12)	SHM19380
	INTEGER DATE, DAY,DPY	SHM19390
100	WRITE(6,1)	SHM19400
1	FORMAT(7X,3HDAY,7X,3HJUN,5X,3HJUL,5X,3HAUG,5X,4HSEPT,5X,3HOCT,5X,	SHM19410
1	3HNOV,5X,3HDEC,5X,3HJAN,5X,3HFEB,5X,3HMAR,5X,3HAPR,5X,3HMAY)	SHM19420
	MEDWY(3)=0	SHM19430



DO 104 DATE = 1,28,1	SHM19440
IF(MOD(DATE,5) .NE. 1) GO TO 102	SHM19450
DO 101 KMO = 1,12	SHM19460
DAY = MEDWY(KMO) + DATE	SHM19470
101 VDMD(KMO) = VDCY(DAY)	SHM19480
WRITE(6,2) DATE,VDMD(12),(VDMD(KWD),KWD=1,11)	SHM19490
2 FORMAT(1H0,3X,I6,3X,12F8.1)	SHM19500
GO TO 104	SHM19510
102 DO 103 KMO=1,12	SHM19520
DAY=MEDWY(KMO) + DATE	SHM19530
103 VDMD(KMO) = VDCY(DAY)	SHM19540
WRITE(6,3) DATE,VDMD(12),(VDMD(KWD),KWD=1,11)	SHM19550
3 FORMAT(1X,3X,I6,3X,12F8.1)	SHM19560
104 CONTINUE	SHM19570
IF(DPY .NE. 366) GO TO 106	SHM19580
DATE = 29	SHM19590
VDCY(60) = VDCY(366)	SHM19600
DO 105 KMO = 1,12	SHM19610
DAY = MEDWY(KMO) + DATE	SHM19620
105 VDMD(KMO) = VDCY(DAY)	SHM19630
WRITE(6,3) DATE,VDMD(12),(VDMD(KWD), KWD=1,11)	SHM19640
GO TO 107	SHM19650
106 CONTINUE	SHM19660
WRITE(6,4) VDCY(302),VDCY(333),VDCY(363),VDCY(29),VDCY(88),	SHM19670
1VDCY(119),VDCY(149),VDCY(180),VDCY(210),VDCY(241),VDCY(272)	SHM19680
4 FORMAT(1X,7X,2H29,3X,4F8.1,8X,7F8.1)	SHM19690
107 CONTINUE	SHM19700
108 WRITE(6,5) VDCY(303),VDCY(334),VDCY(364),VDCY(30),VDCY(89),	SHM19710
1VDCY(120),VDCY(150),VDCY(181),VDCY(211),VDCY(242),VDCY(273)	SHM19720
5 FORMAT(1X,7X,2H30,3X,4F8.1,8X,7F8.1)	SHM19730
WRITE(6,6) VDCY(304),VDCY(365),VDCY(31),VDCY(90),VDCY(151),	SHM19740
1VDCY(212),VDCY(243)	SHM19750
6 FORMAT(1H/,7X,2H31,3X,F8.1,8X,2F8.1,8X,F8.1,8X,F8.1,8X,2F8.1)	SHM19760
MEDWY(3) = 365	SHM19770
RETURN	SHM19780
END	SHM19790
SUBROUTINE PREPRD(RGPM,DRHP,DAY,HOUR,DPY,PRD,PEP,PRH)	SHM19800
C DIVIDES HOURLY PRECIPITATION TOTALS AMONG PERIODS FOR SMALL BASINS	SHM19810
DIMENSION PE4P(4),DRHP(366,24)	SHM19820
INTEGER DAY,DPY,HOUR,PRD	SHM19830
PEP=0.0	SHM19840
IF(PRH .EQ. 0.0) RETURN	SHM19850
IF(PRD .EQ. 1) GO TO 100	SHM19860
PEP = PE4P(PRD)	SHM19870
RETURN	SHM19880
100 LHOURL = HOUR-1	SHM19890
LDAY = DAY	SHM19900
IF(LHOURL .GE. 1 ) GO TO 101	SHM19910
LHOURL = 24	SHM19920
LDAY=DAY-1	SHM19930
IF(LDAY .EQ. 0) LDAY=365	SHM19940
IF(LDAY .EQ. 365) LDAY=59	SHM19950
IF(LDAY .EQ. 59 .AND. DPY .EQ. 366) LDAY=366	SHM19960
101 PRLH = RGPM*DRHP(LDAY,LHOURL)	SHM19970

```

NHOOR = HOUR+1
NDAY = DAY
IF(NHOOR .LE. 24) GO TO 102
NHOOR=1
CALL DAYNXT(NDAY,DPY)
102 PRNH=RGPM*DRHP(NDAY,NHOOR)
IF(PRH .GT. PRLH .AND. PRH .GT. PRNH) GO TO 103
GO TO 104
103 PE4P(1) = 0.10
PE4P(2) = 0.28
PE4P(3) = 0.46
PE4P(4) = 0.16
GO TO 108
104 IF(PRH .LT. PRLH .AND. PRH .LT. PRNH) GO TO 105
GO TO 106
105 PE4P(1) = 0.28
PE4P(2) = 0.10
PE4P(3) = 0.16
PE4P(4) = 0.46
GO TO 108
106 IF(PRNH .GE. PRLH) GO TO 107
PE4P(1) = 0.46
PE4P(2) = 0.16
PE4P(3) = 0.28
PE4P(4) = 0.10
GO TO 108
107 PE4P(1) = 0.10
PE4P(2) = 0.28
PE4P(3) = 0.16
PE4P(4) = 0.46
108 DO 109 KPRD = 1,4
109 PE4P(KPRD) = PE4P(KPRD)*PRH
PEP=PE4P(1)
RETURN
END

```

```

SHM19980
SHM19990
SHM20000
SHM20010
SHM20020
SHM20030
SHM20040
SHM20050
SHM20060
SHM20070
SHM20080
SHM20090
SHM20100
SHM20110
SHM20120
SHM20130
SHM20140
SHM20150
SHM20160
SHM20170
SHM20180
SHM20190
SHM20200
SHM20210
SHM20220
SHM20230
SHM20240
SHM20250
SHM20260
SHM20270
SHM20280
SHM20290
SHM20300
SHM20310
SHM20320

```